NASA Technical Memorandum 101586 Volume I

NASA IN-HOUSE COMMERCIALLY DEVELOPED SPACE FACILITY (CDSF) STUDY REPORT

(NASA-TM-101586-Vol-1) NASA IN-HOUSE COMMERCIALLY DEVELOPED SPACE FACILITY (CDSF) STUDY REPORT. VOLUME 1: CONCEPT CONFIGURATION DEFINITION (NASA. Langley Research Center) 738 p
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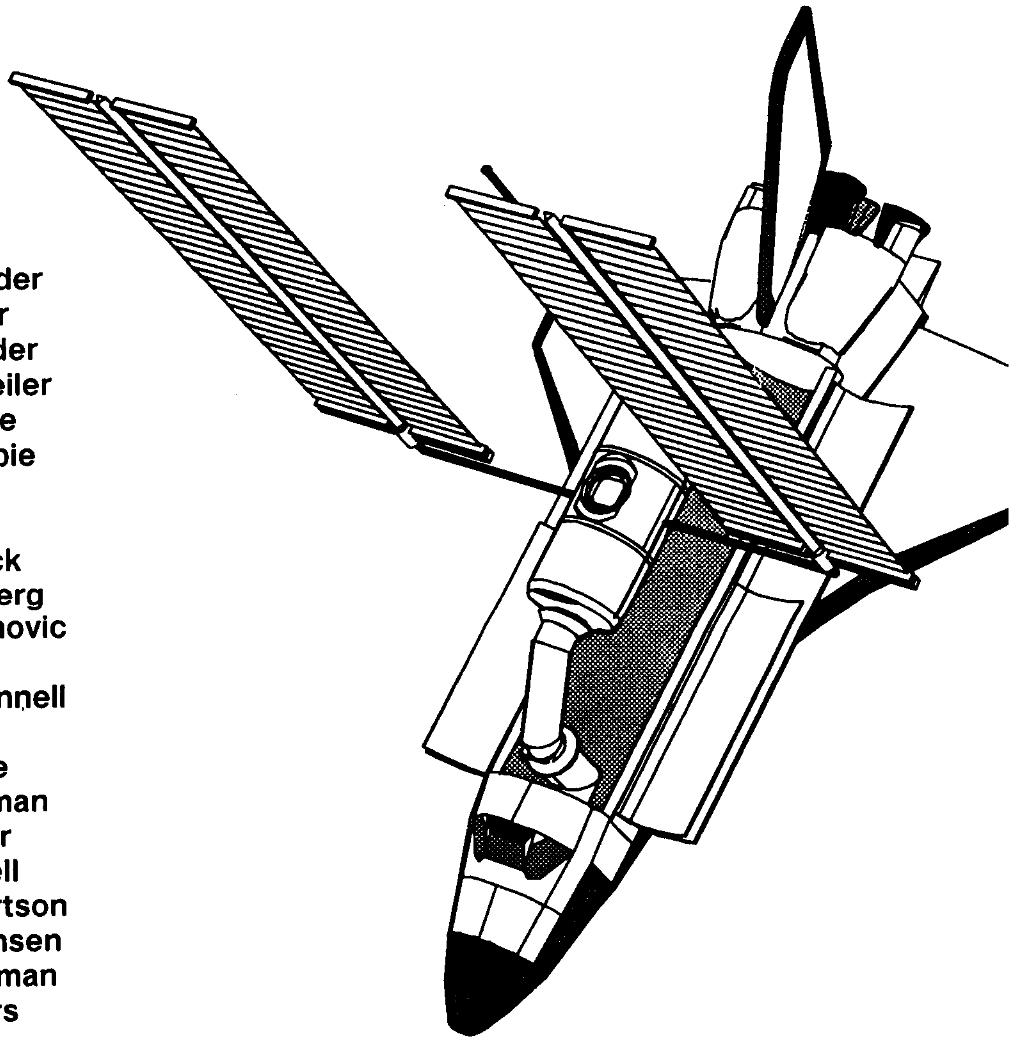
CONCEPT CONFIGURATION DEFINITION



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PREFACE

A February 11, 1988 Presidential Directive on National Space Policy set forth Civil Space Sector guidelines that specifies NASA's lead role within the Federal Government for advancing space science and exploration. Specific Commercial Sector guidelines in this directive states "...that NASA, and the Departments of Commerce, Defense, and Transportation will work together to foster growth of the private sector commercial use of space.." and that all Government agencies "...shall purchase commercially available space goods and services to the fullest extent feasible..."

Since 1987 NASA has considered the use of a commercially developed and maintained space facility, deployed in low earth orbit by the Space Shuttle, for laboratory experiment accommodations on a lease as needed ancillary basis as part of the science hardware development planning for Shuttle Orbiter Experiments (OEX), SPACELAB, and Space Station Freedom programs. Commensurate with the release of the February 1988 Presidential Space Policy Directive, NASA was directed to accelerate efforts to encourage private sector investment in earth orbital space facilities, that could be utilized by all Federal Agencies, by preparing, releasing, and awarding a contract within 5 months to obligate the Government to a 5 year lease for up to 70 % of such a commercially owned and maintained orbital space facility. As a result of Congressional review of NASA's approach and plans for this Commercially Developed Space Facility (CDSF) as it became known during the Spring of 1988, Congress enacted legislation which prohibited release of the Request For Proposal (RFP) until studies were performed which provided more detail than could be documented during the relatively short RFP preparation activities. Additionally, Congress requested NASA, as part of the mandated studies, to perform a lease versus purchase option assessment for the hardware development of the CDSF with the understanding that operation and maintenance of such a facility would be a commercial venture activity.

On September 16, 1988, NASA initiated plans for performing the Congressional legislated CDSF studies. The NASA Office of Space Flight (CSF) was assigned the overall responsibility for the NASA studies and released on September 21, 1988 study management plans which defined the purpose, scope and specific studies to be performed. Public Law 100-685 was signed by the President on November 4, 1988 which officially directed NASA to implement these study plans.

NASA CDSF STUDY MANAGEMENT PLAN SUMMARY

The NASA CDSF study management plans as published by OSF (and included as Appendix A of this report) describe two independent study activities and three specific studies to be performed which are summarized:

I – Congressional Mandated Independent Studies

1 – A study by the National Research Council (NRC) of the CDSF requirements, policy and technical characteristics.

2 – A study by the National Academy of Public Administration (NAPA) of the CDSF program lease versus purchase cost.

II – NASA In– House Study

Concept Definition and Lease versus Purchase Cost studies to be performed based on requirements as defined by the functional performance specifications of the March 24, 1988 draft RFP as prepared by the CDSF Source Evaluation board (SEB) at the Marshall Space Flight Center (MSFC). These studies were to provide concept definition and cost estimates for two CDSF concepts:

Concept #1 – A baseline concept definition and cost estimation that incorporates 100% of the RFP functional performance specifications.

Concept #2 – A concept definition and cost estimation based on minimum assumed capabilities to provide a "bracket" for accommodation of experiment requirements.

The study Management strategy of these independent study activities (I & II) is to provide a comparison of the results of the Concept 1 & 2 definition and cost studies with requirements as inferred from NRC and NAPA advise. This provides NASA with a basis for considering modifications to the SEB produced RFP as required for a cost effective CDSF.

INTRODUCTION

This report documents the results of the NASA In–House CDSF Studies. It consists of two volumes:

Volume I – Commercially Developed Space Facility Configuration Concept Definition

Volume II – Commercially Developed Space Facility (CDSF) Cost and Economic Analysis

Overall OSF study management for these NASA In–House CDSF Studies was the responsibility of the Director of the Commercially Developed Space Facility Program, Mr.Ralph Hoodless, Jr. The Langley Research Center (LaRC) was assigned the lead role for these studies under the direction of Mr. W. Ray Hook, Director of Space. Mr. L. J. DeRyder, LaRC Space Station Freedom Office, provided study team leadership for the Configuration Definition Studies and Mr. J. W. Hamaker, MSFC Program Development Office, was responsible for the Cost and Economic Analysis Studies.

NASA COMMERCIALLY DEVELOPED SPACE FACILITY STUDY REPORT

VOLUME 1

CONFIGURATION CONCEPT DEFINITION CONTROL

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NASA COMMERCIALLY DEVELOPED SPACE FACILITY

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1.0 STUDY OBJECTIVE

NASA IN-HOUSE STUDY OBJECTIVES

The premise of the CDSF spacecraft concept is that the government will lease the capabilities of a low earth orbital space facility that is operated by a commercial venture company. NASA, through an anchor tenant lease arrangement, or through an initial space flight hardware purchase contract, would initiate the development process. A NASA CDSF draft RFP, prepared by a Source Evaluation Board at the Marshall Space Flight Center and included as Appendix B of this report, developed functional performance requirements for the flight hardware and its flight operations utilization. The 5 month RFP development schedule provided limited opportunity to perform systems engineering, flight operations and cost analyses necessary to develop an adequate concept definition for such a space facility.

NASA has been aware for some time of the commercial venture definition activities of Space Industries Partnership (SIP) headed by Space Industries Incorporated (SII) of Houston, Texas and SPACEHAB, Incorporated whose corporate offices are located in Washington ,DC. However, within NASA no concentrated assessments or trade studies had been performed that could serve as a in-house procurement reference for establishing a contractual development activity.

The specific objectives of the NASA in-house concept definition studies provides science mission utilization definition scenarios, quantifies the conceptual configuration system performance parameters, develops benchmark operational scenarios, provides Space Shuttle interface descriptions and assesses development schedule activity with respect to the establishment of a proposed launch date.

Estimates of the design, development and operations cost performed as part of this study are documented in Volume II of this report.

OBJECTIVE OF NASA IN-HOUSE STUDIES

FOR THE GOVERNMENT LEASE OF A COMMERCIALLY DEVELOPED, OWNED AND OPERATED SPACE FLIGHT FACILITY, PERFORM SYSTEMS ASSESSMENTS AND TRADE STUDIES THAT:

- DEFINE MISSION UTILIZATION GOALS;
- QUANTIFY THE CONCEPTUAL CONFIGURATION DEFINITION AND SYSTEM PERFORMANCE PARAMETERS;
- DEVELOP BENCHMARK OPERATIONAL SCENARIOS;
- PROVIDE NSTS INTERFACE DESCRIPTIONS;
- ESTIMATE DESIGN, DEVELOPMENT, PRODUCTION AND OPERATIONS COST;
- ESTABLISH LAUNCH DATE(S);

PROVIDES A REFERENCE CONFIGURATION DEFINITION FOR NASA REQUEST FOR PROPOSAL EVALUATION.

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2.0. STUDY PLAN DESCRIPTION

NASA IN-HOUSE STUDY TASK DESCRIPTION

The NASA In-House Study Task plan is shown. Five main task areas were defined:

1 - Study Initiation

2 - Concept Requirement Definition

3 - Concept Development

4 - Final Cost and Economic Analysis

5 - Final Report Documentation

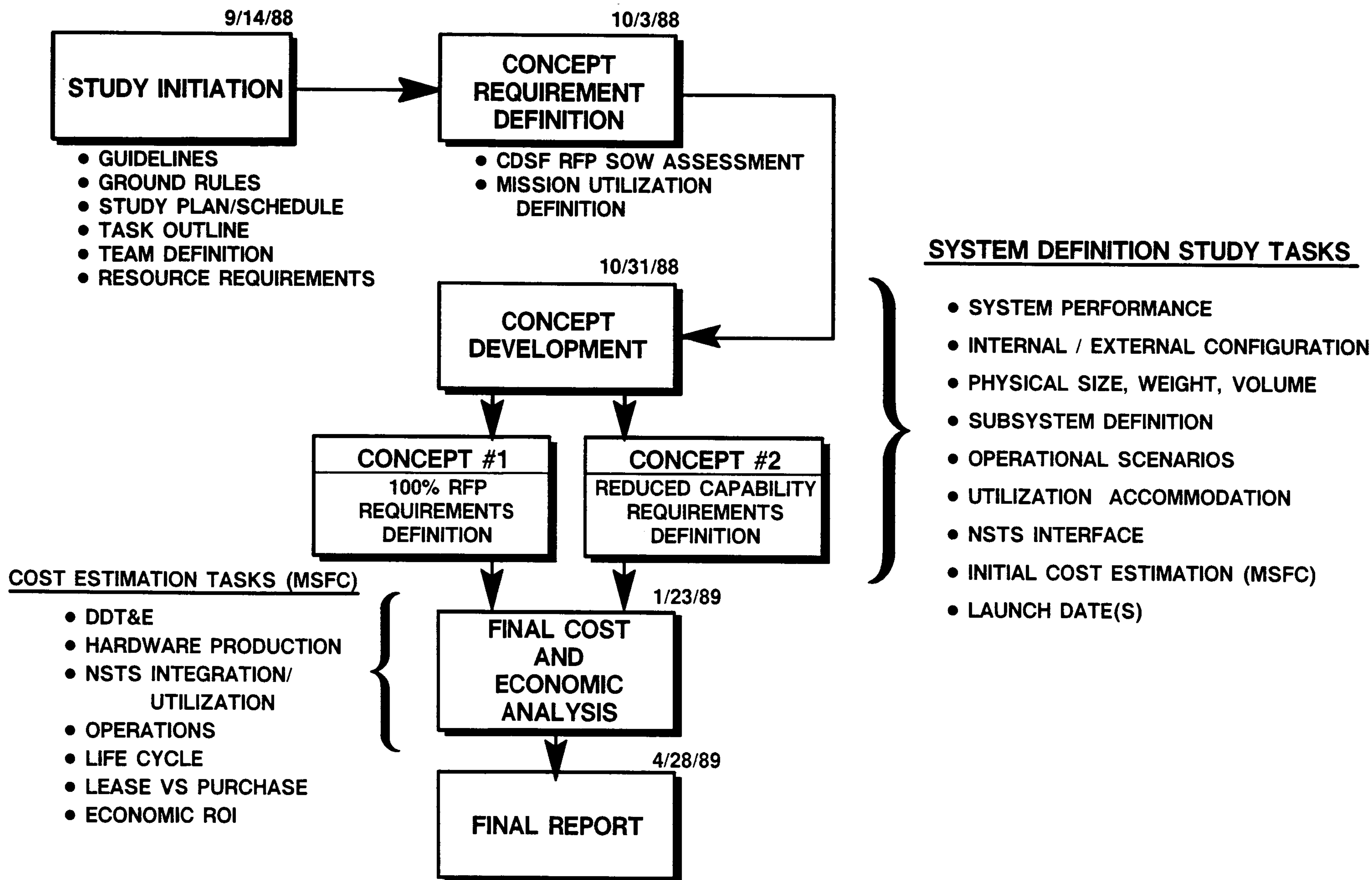
The study initiation task included development and review of guidelines and ground rules (described in section 3.0) to bound the issues to be addressed by the study activity. This study plan and performance schedule (described in this section) was developed along with an initial task outline description depicted as subtasks for each of the major task areas shown. The quantitative results generated from the subtasks shown will be presented as part of this report. A study support team was defined which included participants from other NASA centers. A budget was established to provide contractor support tasks and NASA center institutional support as needed to provide skills and capabilities to perform the various subtasks outlined.

The Concept Requirement Definition task will be discussed in section 4.0, Mission Utilization Definition, and will include assessments of the RFP Statement of Work (SOW).

The Concept Development Task focuses on the definition of two concepts, a concept that incorporates 100% of the Appendix B RFP requirements and a reduced capability concept as previously discussed on page 2, and includes the System Definition subtasks shown. The initial cost estimation performed will be presented in Volume II of this report.

Volume II of this report also documents the Final Cost and Economic subtasks performed which include (1) the required lease versus purchase trade off; (2) concept definition estimates for the two CDSF concepts defined, which includes development, production, operations, launch vehicle integration and utilization, and life cycle costs which includes resupply and maintenance; and (3) an economic return on investment analysis.

NASA IN-HOUSE CDSF STUDY TASK DESCRIPTION

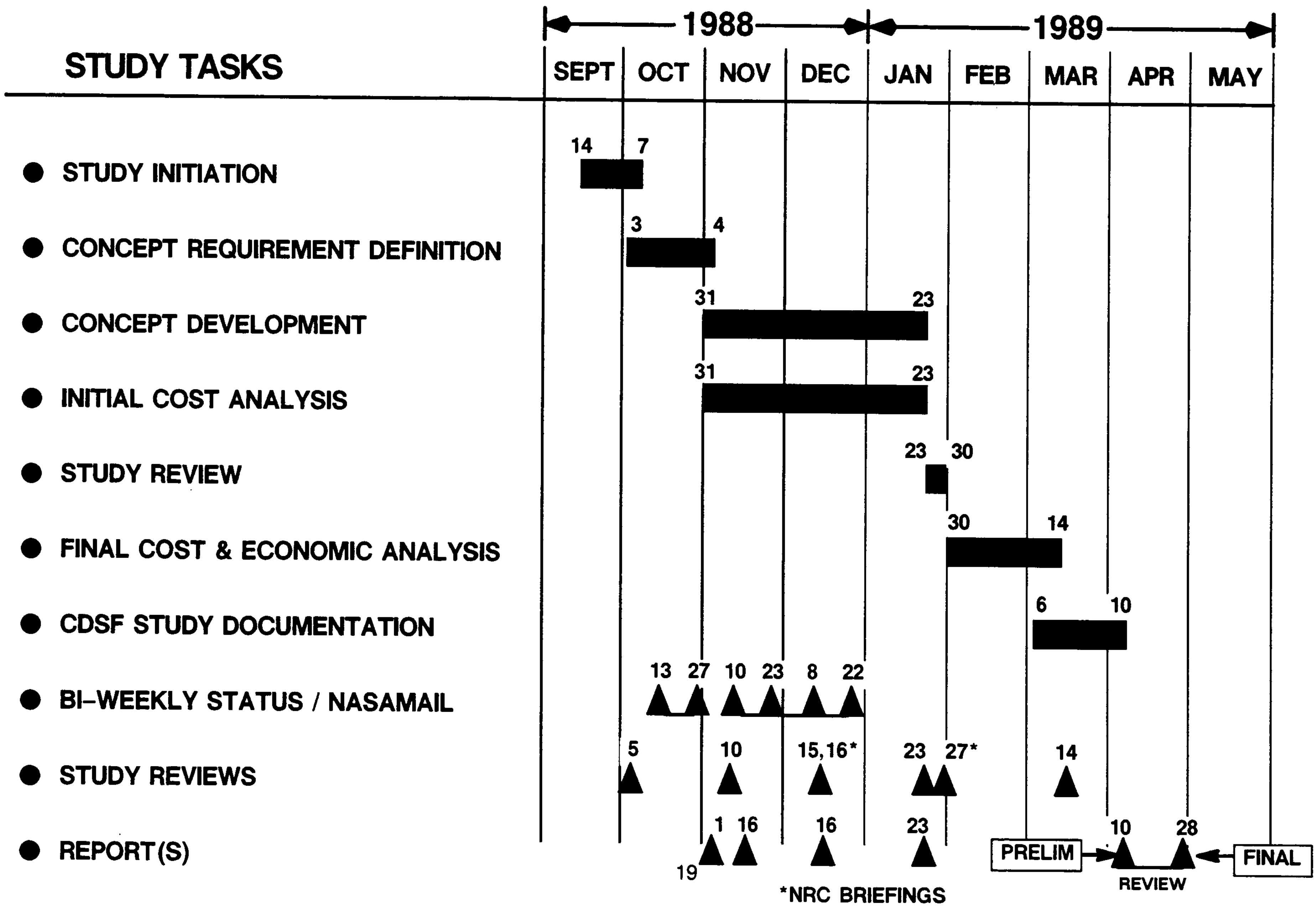


CDSF NASA IN-HOUSE STUDY TASK AND REPORT SCHEDULE

NASA In-House study initiation began in mid September 1988 with review of the OSF study plan draft which was formally released on 9/21/88 to NRC, NAPA and NASA study managers. The NASA In-House Study Plan which included an initial version of this schedule shown was reviewed and approved with modifications at an initial October 5, 1988 Study kick-off meeting. Biweekly status reports were agreed to for the purpose of keeping key NASA managers and study participants informed to permit interactive commentary during the initial concept requirement definition, concept development and initial cost analysis activity.

The study reviews shown were scheduled for the purpose of briefing the NASA Deputy Administrator. After the 12/15/88 and 1/23/89 reviews, status briefings to the NRC were performed as requested. The study review shown for 1/23/89 was originally scheduled as a mid term review by the NASA Deputy Administrator with participation of the Associate Administrator of Space Flight and the Associate Administrator for Space Station Freedom. After review of this study briefing during the week beginning 1/23/88, it was determined that sufficient progress had been made and direction was given by a 1/26/88 letter from the Deputy Administrator that the study team was "...ready to wrap up your present activities and concentrate on writing a final report, ..." The Final Cost and Economic Analyses efforts were completed with the 3/14/88 review as shown which also included a review of the outline for the final report .

CDSF TASK & REPORT SCHEDULE



NASA IN-HOUSE CDSF STUDY TEAM DEFINITION

Study management was assigned to the CDSF Program Director within the NASA Office of Space Flight (Code M). The Langley Research Center was responsible for Study team activities. Systems concept definitions study task leadership was assigned to the Systems Engineering & Integration Office (SEIO) of the LaRC Space Station Freedom Office (SSFO).

Support as required for various study task disciplines was identified as needed within NASA as shown. NASA Headquarters Code M provided Extended Duration Orbiter (EDO) program definition and Shuttle manifest launch schedule advanced planning support. NASA's Office of Space Science (Code E) and Office of Commercial Programs (Code C) provided experiment science mission definition planning study inputs as well as study consultation and review. Marshall Space Flight Center (MSFC) was assigned the responsibility for CDSF cost estimation and economic analysis and also provided initial systems requirements and analysis inputs as derived in support of the Appendix B CDSF RFP. The Johnson Space Center (JSC) provided support in the areas of Shuttle Orbiter flight operations, payload integration and EDO requirements where key CDSF interface definitions were provided by Rockwell International. The Lewis Research Center provided support in the area of spacecraft power system definition and the Kennedy Space Center provided inputs related to prelaunch and post landing STS and payload ground processing and operations.

STUDY TEAM DEFINITION

- **CDSF PROGRAM DIRECTOR PROVIDES STUDY DIRECTION (HOODLESS)**

- **LaRC STUDY TEAM (HOOK)**
  - SSFO/SEIO STUDY TEAM LEAD (DeRYDER)

- **DISCIPLINARY TASK SUPPORT FROM NASA CENTERS:**

  (1) HQ CODE M - EDO, NSTS MANIFEST (BRANSCOME, FITTS)

  (2) HQ CODE E/C - MISSION UTILIZATION DEFINITION(LaRC-MOORMAN/SCHMITZ/ALEXANDER,OTT/WHITTEN)

  (3) MSFC - COST MODELING & ESTIMATION, SYSTEM REQUIREMENTS & ANALYSIS (HAMAKER/PATEL, TAYLOR/ MERIDETH)

  (4) JSC - STS OPERATIONS INTERFACE & INTEGRATION, EDO (WEBB/EGGLESTON, HAVENS, WEARY/RICE)

  (5) LeRC - POWER (REPAS)

  (6) KSC - GROUND PROCESSING & OPERATIONS (MOSAKOWSKI, LYON, MORGAN)

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3.0. GROUND RULES, GUIDELINES, AND ASSUMPTIONS

CDSF PROGRAM GUIDELINES

The fundamental premise of CDSF development is that the Government procures no hardware. The concept of Commercial Sector investment and development is guided by the 1988 Presidential Space Policy directives in this regard. The purpose of studying an option for government purchase of CDSF hardware is to consider the conceptual design differences and cost differences between a commercial venture development approach without Government development specifications and a Government specified development approach.

The primary objective of the CDSF Program is to establish contractual lease arrangements with private venture that would obligate the Government as a 5 year anchor tenant to occupy no more than 70% of available experiment volume and consume no more than 70% of available utility resources. Government lease obligations during the 5 year anchor tenant occupancy period would be based on shared cost arrangements with other commercial users that would utilize at least 30% of the available volume and utility resources. The premise of the lease contract is not to obligate the government to any lease costs until after flight articles are delivered to the proposed launch site and certified for launch into earth orbit.

Over the 5 year Government lease period it is expected that it will be desired to exchange experiment hardware and experiment specimens and to also retrieve experiment products. For this purpose NASA requires the use of the Space Shuttle to provide astronaut mission specialists to tend to experiment operational needs. NASA would consider mission scenarios for crew tended orbital operations utilizing the Shuttle Orbiter for up to 25 days duration.

Concept development guidelines, however, do not exclude the consideration of using expendable launch vehicles (ELV) where applicable and cost effective.

GUIDELINES & GROUND RULES
CDSF PROGRAM GUIDELINES

GOVERNMENT PROCURES NO HARDWARE

- HARDWARE PURCHASE IS AN OPTION TO BE STUDIED

- LEASES 70% OF VOLUME AND UTILITY RESOURCES FOR 5 YEAR PERIOD AS ANCHOR TENANT
- AT LEAST 30% OF VOLUME AND UTILITY RESOURCES AVAILABLE FOR COMMERCIAL USER LEASE DURING ANCHOR TENANT OCCUPANCY
- GOVERNMENT LEASE COSTS BEGIN AFTER FLIGHT ARTICLE DELIVERY AND NASA LAUNCH CERTIFICATION AFTER SCHEDULED LAUNCH DATE
- SPACE SHUTTLE ORBITER WILL BE UTILIZED FOR CREW TENDED ORBITAL OPERATIONS FOR UP TO 25 DAY MISSIONS
  - INITIAL DEPLOYMENT LAUNCH MAY BE SHUTTLE OR ELV

NASA IN-HOUSE STUDY GROUND RULES

Study ground rules were established to provide overall direction to the conduct of the study activity. The fundamental concept of the activity was to perform a concept definition study for the purpose of generating reference configurations and quantifying their performance and cost parameters. The study was to focus on systems and operations definition and no user needs assessment were to be performed as a precursor to establishing sizing parameters. References defined in the RFP were to be used to generate candidate experiment payloads to establish mission scenarios. Two references are given for this purpose:

1 - Microgravity and Materials Processing Facility (MMPF) Study

2 - Requirements and Analysis of Commercial Operations (RACO) Study

These two studies were performed by Teledyne Brown Engineering under contract NAS8-36122 for MSFC. They provide a microgravity experimentation data base to be used to produce CDSF utilization accommodation assessments and to generate mission model scenarios. Mission utilization definition assessments are based entirely on this reference study data. No comparative analysis to other orbital laboratory facilities are performed for purpose of assessment of United States microgravity experimentation needs. National needs assessments are expected to be addressed as part or the NRC studies.

With regard to the NRC and NAPA studies which were performed in parallel to this NASA in-house study, it was determined to keep the two activities as independent as practical but to share data sources to accomplish both activities in a timely manner to meet congressional reporting schedules. Therefore, all coordination of information was through the CDSF Program Director.

GUIDELINES & GROUND RULES
LaRC STUDY GROUND RULES

- STUDY IS A CONCEPT DEFINITION ACTIVITY

- NO USER NEEDS ASSESSMENT TO BE PERFORMED
  - RFP REFERENCES TO BE UTILIZED
  - PRODUCE MISSION UTILIZATION DEFINITION AND UTILIZATION ACCOMMODATION ASSESSMENT THAT ADDRESSES MICROGRAVITY EXPERIMENTATION

- PERFORM NO COMPARATIVE ANALYSIS TO OTHER ORBITAL LABORATORY FACILITIES (i.e., Skylab, Spacelab, Spacehab, ISF, EDO, Mir, Freedom)

- RESPONSE TO NRC AND NAPA INPUTS WILL BE THROUGH CDSF PROGRAM DIRECTOR

CDSF RFP GUIDELINES FOR NASA IN-HOUSE STUDIES

The March 24,1988 draft RFP prepared by NASA requests industry to submit proposals that describe the mission hardware and the leased services to be offered. The key requirements established for the hardware and the leased services set specific guidelines for this study activity.

It is intended that the CDSF contractor will provide all necessary hardware to accomplish NASA's utilization of the CDSF. That hardware is defined to be the elements that will be launched into earth orbit that make up the experimental facility which includes elements for resupply and logistics. It also includes all ground support equipment (GSE) and airborne support equipment (ASE) for processing all space flight hardware for prelaunch and post landing operations. As will be addressed in this study, it also includes any experiment processing, mission control and data handling, and training hardware and facilities. The intent of these guidelines is to keep to a minimum the dependency on Government furnished equipment (GFE) to support the proposed 5 year CDSF mission and to depend on a lease arrangement to obtain use of these hardware and facilities.

For the purpose of this study, guidelines for leased services as specified by the draft RFP are for an initial deployment mission and define a reimbursible NSTS dedicated Shuttle Orbiter standard services launch cost of 110 million dollars for initial CDSF deployment. Partial utilization is to be prorated using published NSTS pricing guidelines. Ground integration test and check-out leased services, including all integration documentation, is defined to be provided for prelaunch and post landing mating and de-mating of the CDSF in the Orbiter cargo bay. Payload hardware and software leased services is defined to be provided for installation, changeout and removal of Government experiment hardware with the CDSF. Mission planning and mission operations support services are defined to be provided for (1) Shuttle missions involving crew tended operations which are ground ruled to utilize the NASA JSC mission operation control facilities and (2) free flier mission support for experiment operation and science data handling.

GUIDELINES & GROUND RULES
CDSF RFP GUIDELINES

- **LEASED HARDWARE INCLUDES:**
  - (1) – Orbital Space Laboratory Facility
  - (2) – Ground Support Equipment (GSE) and Integration Facility
  - (3) – Airborne Support Equipment (ASE)

- **LEASE SERVICES INITIALLY PROVIDE:**
  - (1) – CDSF Launch and Deployment and Return of Experiments
    - Reimbursible @ $110 M – FY 88 – Standard Services
  - (2) – Ground Integration Test & Checkout for Initial Launch
    - Includes Launch Vehicle Integration Documentation
  - (3) – Payload Hardware and Software Integration for Initial Launch
    - Includes Payload Integration User Documentation
  - (4) – Mission Planning & Operations & OPS Facility for Initial Launch
    - Includes Government Mission Specialist & Flight Controller Training

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4.0. CONCEPT REQUIREMENT DEFINITION

KEY CDSF MISSION CONCEPT REQUIREMENTS

The purpose of this study is to define a NASA reference concept. The initial task toward achieving this objective was to define , understand and assess the salient requirements that are concept drivers. A statement of CDSF mission objectives was developed from the Appendix B RFP specifications. As listed here, they provide the definition for the CDSF Mission concept.

A dual purpose spacecraft is required which provides operational capabilities in both an unattended orbital free flight mode and also in a flight mode attached to the Shuttle Orbiter. The Shuttle attached crew-tended mode requires the CDSF to provide an environment to safely support human life and a laboratory area that allows operation of scientific experiments and production of materials in a low gravity environment. The key objective for the free flight mode is to permit long term automated undisturbed experimentation and production opportunities.

While other options may be considered, it is NASA's intent to support the deployment of this space laboratory facility with a single shuttle launch to facilitate utilization of the previously described operational capabilities. A revisit capability is required over the intended 5 year lease period to allow for experiment hardware change out and resupply logistics. At this point in time, NASA envisions a need for resupply visits with the Space Shuttle every 4–6 months for this purpose.

Due to the possibility of a NASA NSTS stand down due to potential grounding of the Shuttle Fleet, it is required that CDSF systems be sized for a 3 year unattended operational capability. NASA also requires that the CDSF system design initially take into account the removal from low earth orbit of this facility after completion of its useful productive life.

KEY CDSF MISSION CONCEPT REQUIREMENTS

- PROVIDE CREW–TENDED HANDS–ON MICROGRAVITY SCIENCE AND RESEARCH OPPORTUNITIES IN THE ATTACHED–TO–ORBITER MODE
- PROVIDE LONG–TERM AUTOMATED MATERIALS PROCESSING AND PRODUCTION OPPORTUNITIES WHILE IN FREE–FLYER MODE
- DEPLOY A FULLY FUNCTIONAL CAPABILITY IN ONE STS MISSION
- PROVIDE FOR NSTS REVISIT CAPABILITY
  - INITIAL EXPERIMENT COMPLIMENT CHANGE–OUT
  - RESUPPLY / LOGISTIC MISSIONS EVERY 4–6 MONTHS
  - SYSTEMS SIZED FOR 3 YEARS UNATTENDED OPERATION
- RE–ENTRY, RETURN, OR DISPOSAL AT END OF LEASE OR USEFUL LIFE

REQUIREMENTS FOR CDSF MISSION PLANNING

Specific requirements have been established by NASA related to utilization of the Shuttle Orbiter which are key concept sizing considerations and constraints.

At this time it is NASA's intention not to specifically commit any particular Shuttle Orbiter vehicle for use for the initial CDSF deployment launch. Since the Shuttle Orbiter Columbia (OV-102) has a payload lift performance 8,400 pounds less than other vehicles in the orbiter fleet, for orbital inclinations of 28.45 +0.1 degrees, the STS payload lift performance to an altitude of 160 nautical miles is currently established to be 46,030 pounds for CDSF concept definition considerations. STS performance is specified in the Appendix B RFP.

The RFP also specifies specific STS performance parameters for CDSF revisit missions which are also CDSF concept definition sizing considerations. 174 or 202 nautical mile STS rendezvous altitudes provide desirable regular repeating orbital launch window opportunities of every second day and every third day respectively for a given launch date. The Right Ascension of the Ascending Node (RAAN) requirement is derived from a NSTS desire to be able to service multiple missions per flight such as a CDSF revisit mission and an alternate satellite deployment or rendezvous mission which also presumably has an orbital ascending node requirement. Because the normal nodal regression of an earth orbiting CDSF is altitude dependent, a RFP requirement is specified to adjust the orbital altitude every 4 to 6 months by an amount which results in a CDSF orbit nodal regression change of 0.2 degree per day. For concept sizing, this rate, or delta RAAN, is currently specified to be maintained for nominal revisit planning intervals of 180 days.

For revisit flight operations, it is NASA's desire that the CDSF be compatible with the entire Shuttle Orbiter fleet including the planned Extended Duration Orbiter (EDO) to permit mission stay times of up to 25 days.

REQUIREMENTS FOR CDSF MISSION PLANNING

- CDSF CONCEPT DEFINITION MUST PERMIT INITIAL DEPLOYMENT WITH STS OV-102 (COLUMBIA)

- RFP REQUIRES CDSF DEPLOYMENT FROM NEAR CIRCULAR EARTH ORBIT
  - ALTITUDE = 160 NAUTICAL MILES
  - INCLINATION = 28.45 ±0.1 DEGREES

- RFP SPECIFIES PARAMETERS FOR
  - NOMINAL REVISIT INTERVAL = 6 MONTHS
  - RENDEZVOUS ALTITUDE = 174 OR 202 NAUTICAL MILES
  - RIGHT ASCENION OF ASCENDING NODE = NSTS SPECIFIED ±1 DEGREE AT AN ADJUSTED RATE OF 0.2 DEGREE / DAY BETWEEN REVISITS
  - STS STAY TIME = UP TO 25 DAYS

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4.1. RFP SOW FUNCTIONAL REQUIREMENT ASSESSMENT

CDSF REQUEST FOR PROPOSAL (RFP) CONCEPT REQUIREMENTS

NASA's initial conceptual CDSF definition was established as part of the Source Evaluation Board RFP planning. This activity, based at the Marshall Space Flight Center, generated key system sizing parameters to scope a CDSF concept based on assessments of NASA space science and commercial program needs. Utilizing these initial concept requirements for system sizing provided two assessment opportunities for the NASA in-house studies. As previously stated,it provided the opportunity to derive a configuration definition based on the requirements as specified in the draft RFP. It also provided the opportunity to test and evaluate these requirements to permit appropriate adjustments to be made prior to release of the final RFP.

The specification for experiment volume requires the CDSF racks to provide no less than 300 cubic feet minimum of usable volume for user hardware. This is not to include rack utilities such as power, thermal and data services. To support 25 day EDO missions, the CDSF must also provide 50 cubic feet of STS crew stowage space.

The steady state microgravity sensed acceleration requirement is currently specified as time varying disturbances at or less than 0.1 HZ to be less than 32.2 ft.*1E-6/sec**2 at the center of mass of the CDSF configuration. It is required that this level be maintained for periods of up to 30 days in the free flier mode of operation.

CDSF RFP CONCEPT REQUIREMENTS

EXPERIMENT VOLUME

- 300 CU. FT. MINIMUM USEABLE VOLUME WITHIN CDSF FURNISHED RACKS
- 50 CU. FT. EDO STS CREW STOWAGE SPACE
- ACCOMMODATE EXISTING SPACELAB HARDWARE EXPERIMENT RACK MINIMUMS OF:
  - -- 17.425 INCHES WIDE BY 29.094 INCHES DEEP
  - -- 25 LB/FT^3 INTEGRATED RACK DENSITY

MICROGRAVITY ENVIRONMENT

- 1×10^{-6} g FOR FREQUENCIES BELOW 0.1 Hz AT C.G. FOR 30 DAYS IN THE FREE FLIER MODE

CDSF REQUEST FOR PROPOSAL (RFP) CONCEPT REQUIREMENTS (Continued)

Environmental control requirements specify that the CDSF design shall permit a habitable shirt sleeve environment for two mission specialist STS crew to work for mission stay times of up to 25 days. Free flier flight mode requirements specify that a nominal sea level atmospheric pressure be maintained in the CDSF such that user equipment does not have to be designed to operate at reduced pressure and cooling of equipment is facilitated. In the free flier mode, this requirement does not extend to providing an atmosphere capable of supporting human or animal life.

Power requirements for the CDSF specify that an average of 7 kilowatts of power be made available to users exclusive of subsystem support demand. Additionally it is required that a minimum of the experiment rack locations be made available to accommodate "total power available on a time lined basis." It is also specified that if solar arrays are used for power generation that the blanket area will be required to track the sun in the orbiter attached mode.

CDSF RFP CONCEPT REQUIREMENTS

(Continued)

ENVIRONMENTAL CONTROL

- PRESERVE A HABITABLE SHIRT SLEEVE ENVIRONMENT FOR UP TO 2 CREWMEN FOR UP TO A 25-DAY EDO MISSION
- MAINTAIN A ONE ATMOSPHERE PRESSURE FOR EXPERIMENT VOLUME IN FREE FLYER MODE
  -- HUMAN OR ANIMAL LIFE SUPPORT NOT REQUIRED

POWER

- AT LEAST 7 KW AVERAGE POWER TO USERS @ 28 ± 4 V DC
  -- "TOTAL POWER AVAILABLE" AT 3 RACK LOCATIONS ON A TIMED BASIS
- SUN TRACKING SOLAR ARRAYS IN THE ATTACHED-TO-ORBITER MODE

CDSF REQUEST FOR PROPOSAL (RFP) CONCEPT REQUIREMENTS (Continued)

Command and data management requirements specify communications through the NASA Tracking and Data Relay Satellite (TDRSS), or alternate system, at data rates of at least 16 KBPS, shared among facility housekeeping and user equipment. Data storage and retrieval capabilities are required on board when direct communications is not possible. A command uplink of 1 KBPS is required.

Operability, accessibility and maintainability requirements specify that provisions for replacement of user equipment be accommodated at the rack level while attached to the Shuttle Orbiter. Orbit replaceable unit systems design for maintainability is implied but not required.

CDSF RFP CONCEPT REQUIREMENTS

(Continued)

COMMAND AND DATA MANAGEMENT

- COMMUNICATION THROUGH NASA TDRSS, OR ALTERNATIVE SYSTEM
  - -- 16 KBPS SCIENCE AND ENGINEERING SCIENCE DATA DOWNLINK
  - -- 1 KBPS COMMAND UPLINK

OPERABILITY / ACCESSIBILITY / MAINTAINABILITY

- USER HARDWARE REPLACEMENT AT RACK LEVEL WHILE STS ATTACHED
- ORBIT REPLACEABLE UNIT SYSTEMS DESIGN FOR MAINTAINABILITY REQUIRING STS

KEY CDSF ELEMENTS SPECIFIED BY NASA REQUEST FOR PROPOSALS (RFP)

Four key space flight hardware elements are identified by the conceptual functional requirements stated in the appendix B RFP that must be developed and provided for use. As shown, they are:

1 - A free flying spacecraft with a pressurized experiment laboratory section.

2 - A Shuttle Orbiter docking module capable of providing STS crew shirt sleeve access to the CDSF laboratory area.

3 - A STS compatible resupply module capable of permitting user equipment whole system change out and replacement at the rack level.

4 - A equipment rack compatible for use with existing SPACELAB experiment hardware.

While SPACELAB compatibility is an explicit RFP requirement, NASA also desires that potential CDSF developers consider compatibility with Space Station Freedom payload interfaces currently under development. This consideration would help to assure that planning for microgravity space research equipment and facilities follow a logical progression of capability maturation in space.

The following sections of this report will present system engineering analysis results and sizing estimates for these space flight elements. A key concept sizing factor is the requirement to consider the use of Shuttle Orbiter Columbia as an initial deployment launch vehicle. This requirement is not seen as a major CDSF concept impact as several trade off options are available as will be addressed. However it is a major spacecraft sizing driver.

RFP SPECIFIES KEY ELEMENT DEVELOPMENT FOR LEASE / PURCHASE UTILIZATION

1. **FREE FLYING SPACECRAFT**

   -- PRESSURIZED 30 DAY 1 MICRO G EXPERIMENT FACILITY

2. **STS CREW TENDED DOCKING MODULE**

   -- PROVIDE SHIRT SLEEVE STS / CDSF ENVIRONMENT

3. **STS COMPATIBLE RESUPPLY MODULE**

   -- EXPERIMENT CHANGE OUT AT RACK LEVEL

4. **EXPERIMENT RACK**

   -- COMPATIBLE WITH SPACELAB EXPERIMENT HARDWARE

STS 102 VEHICLE PERFORMANCE MAJOR S/C SIZING DRIVER

-- SETS VOLUME AND WEIGHT LIMITS FOR INITIAL DEPLOYMENT LAUNCH OPERATIONAL CAPABILITY

REQUIREMENTS FOR CDSF OPERATIONAL SUPPORT ELEMENTS

Four categories of CDSF operations support elements are identified to be provided as part of the development requirements specified by the Appendix B RFP. ASE and GSE concepts will not be addressed in detail as part of the concept definition part of this study. Flight weights for ASE have been accounted for as related to Shuttle Orbiter cargo bay accommodation and launch performance. Cost models have been developed based on past programs such as SPACELAB to account for development estimates for these items. Volume II of this report will discuss this area of cost estimation.

STS flight operation training aids are required by the NSTS to develop and practice crew procedures and techniques. The concept definition for these elements were also not addressed as part of these NASA in house studies. Volume II of this study addresses the cost modeling and estimates for these elements. The concept definitions as developed for this study does not require Shuttle Orbiter extravehicular activity (EVA) for CDSF deployment, resupply and disposal missions. Therefore, the need for a Weightless Environment Training Facility (WETF) mock up is not considered as a cost element.

CDSF OPERATIONAL SUPPORT ELEMENTS

- AIRBORNE SUPPORT EQUIPMENT (ASE)
- GROUND SUPPORT EQUIPMENT (GSE)
- STS FLIGHT OPERATION TRAINING AIDS
  - -- SHUTTLE MISSION SIMULATOR VISUAL MODEL
  - -- SHUTTLE MISSION SIMULATOR MATH MODEL
  - -- SHUTTLE ENGINEERING SIMULATOR DYNAMIC FUNCTIONAL MODEL
  - -- CREW PROCEDURE AND TECHNIQUE ONE g CDSF MOCK-UP
  - -- RMS NEUTRAL AIR BUOYANT CDSF MOCK-UP
  - -- WETF NEUTRAL WATER BUOYANT MOCK-UP (IF EVA NEEDED)
  - -- MISSION SPECIALIST HIGH FIDELITY CDSF MOCK-UP
- FLIGHT OPERATIONS CONTROL FACILITY

NASA CDSF REQUEST FOR PROPOSAL (RFP) CONCEPT REQUIREMENT ISSUES

A summary of the Appendix B RFP review task performed as part of this study is presented. Four concept requirement issues are identified.

It is not apparent that a need exists that substantiates the requirement for CDSF solar arrays to track the sun while attached to the Shuttle Orbiter. As will be discussed, assessment of candidate experiments and CDSF mission scenarios developed as part of this study for crew tended missions do not require large enough power consumption to justify this need. As will be discussed, it also creates an undesirable flight control stability impact due to the operation of a rotating mechanism (alpha joint) and increases the acceleration levels as sensed by the on board microgravity experiments.

The requirement for deployment at a specified altitude of 160 nautical miles creates undesirable sizing constraints when follow on revisit missions and a 3 year contingency altitude are considered. Rendezvous and reboost assessments will be presented to address this issue. The 600 pound penalty to implement the Right Ascension of the Ascending Node (RAAN) will also be discussed.

A review of microgravity experiment requirements as listed in the RFP reference documents points to sensed acceleration vector direction requirements of ± 5 degrees. The interpretation of the application of this requirement can be a key configuration definition and subsystem sizing driver as will also be discussed in the flight mode microgravity environment assessment section of this report.

RFP CONCEPT REQUIREMENT ISSUES

- NEED FOR SUN TRACKING SOLAR ARRAYS WHILE ATTACHED TO STS
  - -- ALPHA JOINT REQUIREMENT DRIVER
  - -- NOT NEEDED FOR P/L POWER
- 160 NMI INITIAL DEPLOYMENT ALTITUDE
- 0.2 DEG/DAY RAAN REQUIREMENT IMPOSES A 600 # REBOOST FUEL PENALTY
- RFP DOES NOT RECOGNIZE +/– 5 DEGREE MICRO–G VECTOR DIRECTION REQUIREMENT
  - -- KEY CONFIGURATION/SUBSYSTEM DRIVER

NASA

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4.2. MISSION UTILIZATION DEFINITION

CDSF MISSION UTILIZATION DEFINITION

The initial steps of this task were to review the draft RFP (Appendix B) reference documents, specifically the Microgravity and Materials Processing Facility (MMPF) Study and the Requirements and Analysis of Commercial Operations (RACO) Study reports to understand experiment descriptions, experimental facility data and system requirements. Various other NASA microgravity program reports were also reviewed from the Offices of Space Science and Commercialization. A complete list of review references are listed on the following page of this report. The purpose of reviewing these documents was to develop a candidate set of experiments from which to generate potential CDSF mission models and scenarios to test the capabilities of the CDSF concept definitions to be developed in this study. No attempt was made to establish user needs or define experiment requirements but rather to review information that had been published to date in this regard. The objective of this task was to generate CDSF spacecraft and mission characteristics that defined the microgravity accommodation environment, orbital facility sizing parameters and mission operational needs to accomplish experiment goals.

CDSF MISSION UTILIZATION DEFINITION

- REVIEW OF DRAFT RFP REFERENCE DOCUMENTS

- REVIEW OF NASA MICROGRAVITY PROGRAM REPORTS
  - -- SPACE SCIENCE
  - -- COMMERCIALIZATION

- DEFINITION OF CANDIDATE EXPERIMENTS FOR CDSF MISSIONS

- GENERATION OF POTENTIAL CDSF MISSION MODELS AND SCENARIOS

- DEFINITION OF SPACECRAFT AND MISSION CHARACTERISTICS
  - -- MICROGRAVITY ENVIRONMENT
  - -- SIZING PARAMETERS
  - -- EXPERIMENT OPERATIONAL NEEDS

NASA IN-HOUSE STUDY REPORT REFERENCES

Listed are the reference reports used in the mission utilization definition definition study task. Item 1 is the Appendix B draft RFP reference document.

NASA MICROGRAVITY STUDY REPORT REFERENCES

1. MICROGRAVITY AND MATERIALS PROCESSING FACILITY STUDY (MMPF), REQUIREMENTS AND ANALYSIS OF COMMERCIAL OPERATIONS (RACO), CONTRACT NAS8-36122 REPORT, MARCH 8, 1988.

2. NASA MICROGRAVITY STRATEGIC PLAN - 1988.

3. MICROGRAVITY SCIENCE AND APPLICATIONS, APPARATUS AND FACILITIES; NASA MICROGRAVITY BROCHURE; NASA OFFICE OF SPACE SCIENCE, MICROGRAVITY SCIENCE DIVISION, PRODUCED BY MARSHALL SPACE FLIGHT CENTER, JANUARY 1988.

4. ACCELERATION REQUIREMENTS AND MICROGRAVITY SCIENCE AND APPLICATIONS EXPERIMENTS IN THE SPACE STATION ERA, R. J. NAUMAN; JUNE 1988.

5. COMPLEMENTARY USE OF SPACE STATION AND CDSF FOR MICROGRAVITY EXPERIMENTS; R. J. NAUMAN; JUNE 1988.

6. SPACE VEHICLE MICROGRAVITY ENVIRONMENTS AND PAYLOAD MICROGRAVITY REQUIREMENTS; SPACE STATION FREEDOM PROGRAM OFFICE DOCUMENT #SSE-E-88-R21, SEPTEMBER 1988.

7. LETTER REPORT: FRANKLIN D. LEMKEY, DIRECTOR, NASA OFFICE OF SPACE SCIENCE MICROGRAVITY SCIENCE AND APPLICATION DIVISION; TO DR. ROBERT H. KORKEGI, DIRECTOR, AERONAUTICS AND SPACE ENGINEERING BOARD, COMMISSION ON ENGINEERING AND TECHNICAL SYSTEMS, NATIONAL RESEARCH COUNCIL, JANUARY 9, 1989.

REQUIREMENT DRIVERS FOR CDSF MISSIONS AND SPACECRAFT CONFIGURATION

Experiment acceleration accommodation levels are a key requirement to establish for the CDSF concept definition. A review of the acceleration levels experienced on microgravity experimentation missions flown to date using the SPACELAB facility in the Space Shuttle cargo bay shows that only portions of the laboratory facility are exposed to the one micro-g environment and that dynamic disturbances of up to 4000 micro g are experienced at the center of mass of the lab due dynamic disturbances which include vernier thruster firing and crew motion (see reference 6 on the preceding page). As will be presented, microgravity experiment requirements have been defined in the reference study reports that range from one to one hundred micro g. Micro g levels below 100 micro g are best accommodated in a free flying spacecraft mode. However, section 5.2 of this study analyzes and presents requirements for a CDSF concept definition to satisfy low level space flight acceleration levels in both a free flier and a Shuttle attached crew tended mode.

Crew operation of experiments is a key requirement for some experiment definitions and must be provided for in the CDSF concept definition. Some experiments have multiple run requirements and require several experiment products to be generated. Others have setup and calibration requirements for which interactive crew presence is critical. As will be seen, some experiments require run times in excess of what can be accommodated on a Shuttle extended duration mission and must be operated remotely or autonomously in a free flier spacecraft mode.

In establishing spacecraft size parameters for a CDSF facility it is obvious that a set of mission scenarios must be established to scope what can be allocated or best performed with a Shuttle crew tended mission, a free flier mission or a mission which requires both flight modes. A candidate CDSF experiment list was generated for this purpose.

MISSION UTILIZATION DEFINITION

REQUIREMENT DRIVERS FOR CDSF MISSIONS AND SPACECRAFT CONFIGURATION

- EXPERIMENT MICRO G LEVEL DEFINITIONS

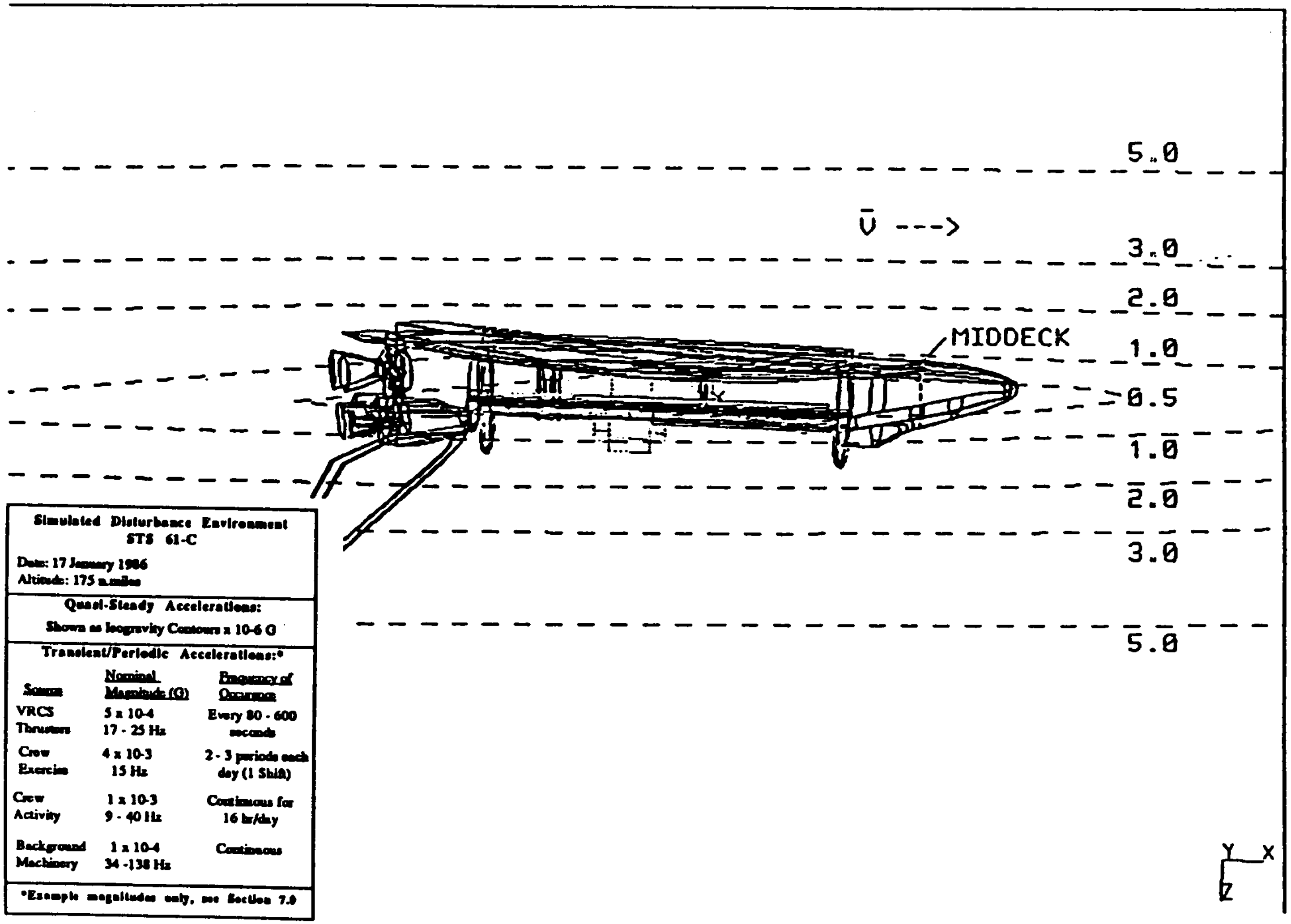
- EXPERIMENT OPERATION
  - RUN TIME
  - CREW OPERATION
  - AUTONOMOUS OPERATION

- EXPERIMENT UTILITY NEEDS
  - VOLUME, WEIGHT, POWER, THERMAL, DATA, VENTING

STS 61-C MICROGRAVITY EXPERIMENTAL MISSION

Microgravity acceleration accommodation levels that have been experienced on past Shuttle missions are represented here with an example from CDSF study reference 6. While the nose forward in the direction of the flight path allowed the entire cargo bay of the Shuttle Orbiter to be encompassed in a one micro g steady state envelope as shown, this orientation is not a stable flight attitude and this condition could not be sustained longer than 80 seconds due to orbiter vernier reaction control system (VRCS) firings. Crew disturbances due to exercises for this mission show responses measured at the vehicle center of mass to be 4000 micro g at 15 HZ.

STS 61–C MICROGRAVITY EXPERIMENTAL MISSION



PLANNED USML MISSION

As documented in the CDSF study reference 6, planning for the USML-1 (United States Microgravity Laboratory Mission) using the SPACELAB module scheduled for March 1992 is shown with the Shuttle Orbiter oriented in a flight mode orientation with length the of its cargo bay aligned to nadir and its wing tips aligned in the direction of the flight path. This flight orientation is also not entirely stable as VRCS thruster firings are predicted to occur at least every 20 minutes. While this mission offers a steady state micro g accommodation environment almost an order of magnitude better than the the STS 61C mission previously described, low frequency dynamic disturbances are also predicted as shown. The relationship of these dynamics disturbances will be described in section 5.2 of this report.

PLANNED USML MISSION

Simulated Disturbance Environment
USML-1 (STS-58)

Date: 26 March 1992
Altitude : 160 Nmi

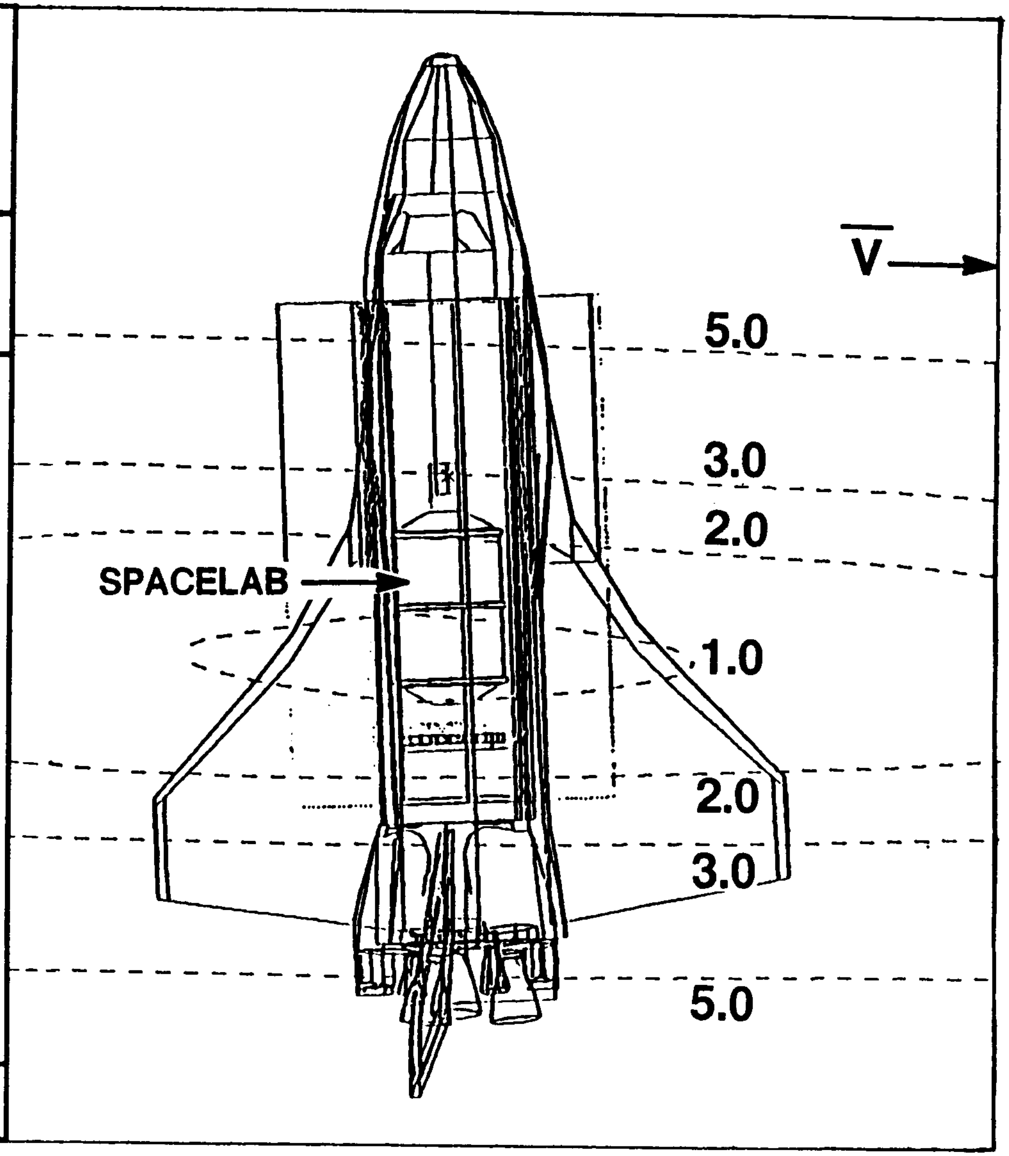
Quasi-Steady Accelerations:

Shown As Low Gravity Contours X 10^{-6} G

Transient/Periodic Accelerations: *

Source	Nominal Magnitude (g)	Frequency Of Occurance
VRCS Thrusters	5×10^{-4} 17 - 25 Hz	Every 1000-1200 seconds
Crew Exercise	7×10^{-4} 15 Hz	2-4 periods each day (2 shifts)
Crew Activity	5×10^{-4} 9 - 40 Hz	Continuous 24 hrs/day
Background Machinery	8×10^{-4} 34 - 138 Hz	Continuous
S/L Module Trunnion Friction	1×10^{-2} 13 - 20 Hz	Once per day (maximum)

* Example magnitudes only, see Section 7.0



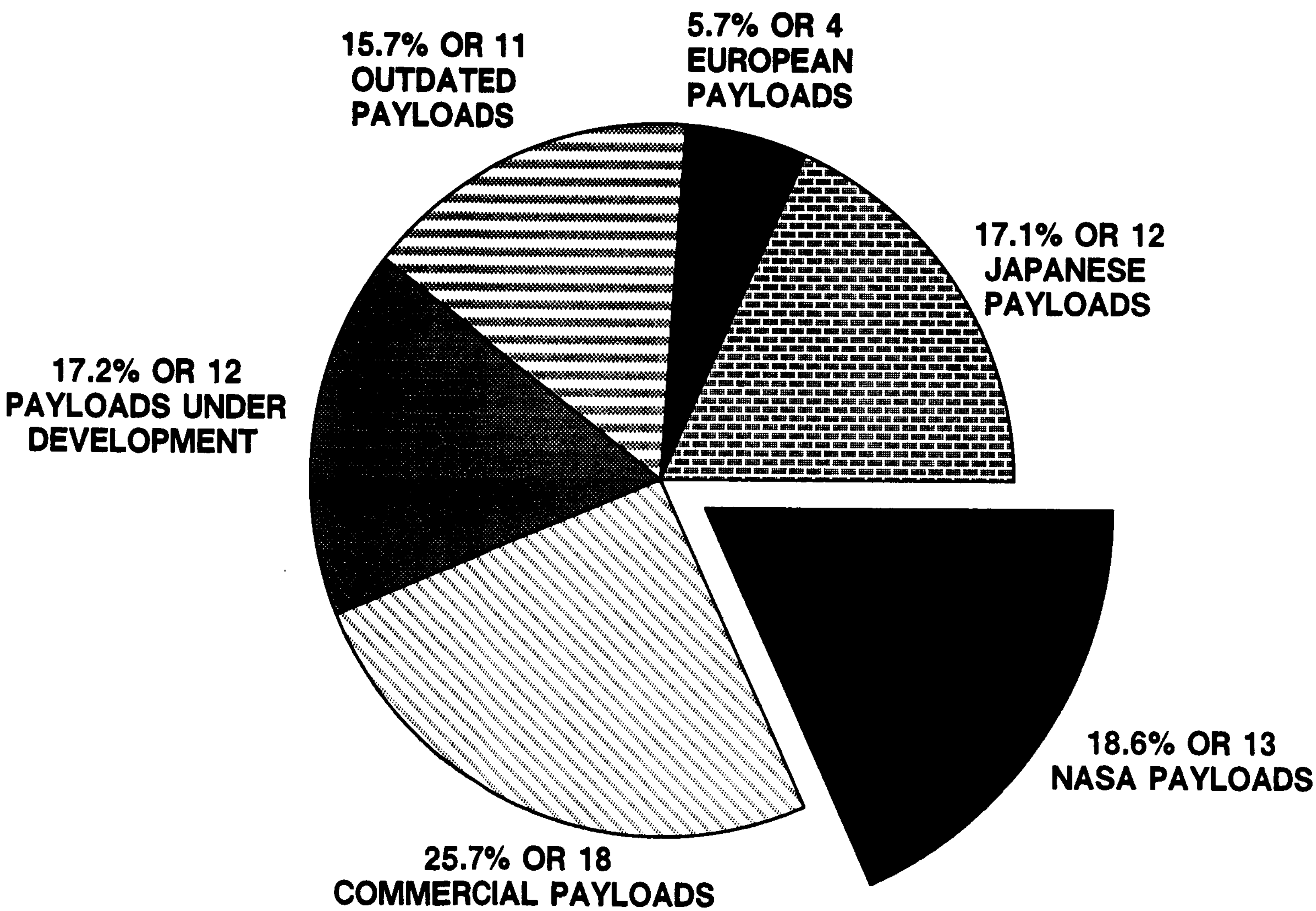
SSE-E-88-R21

RACO STUDY EXPERIMENT DEFINITION SUMMARY

Shown is a summary of the experiment categories as documented in the Appendix B Requirements and Analysis of Commercial Operations (RACO) study. A total of 70 experiments were defined. Eleven of these experiments were classified as outdated. Twelve were international payloads for which no agreements are envisioned to be included as part of CDSF mission utilization. (This is a study assumption based on the absence of any reference to international participation as part of the space commercialization statements of the 1988 Space Policy declarations. Any commercial venture which includes manifesting foreign experiments is assumed to be included in the 30% portion of the CDSF leased volume and resources for which the CDSF contractor assumes responsibility.)

The resulting 43 RACO experiments were used to form an initial CDSF candidate experiment list. The next step was to compare this list to current NASA Offices of Space Science (Code E) and Commercial Programs (Code C) program planning to develop a final candidate experiment list for use in the NASA in-house CDSF study activity.

RACO EXPERIMENT DEFINITION STUDY



RACO STUDY POWER REQUIREMENTS

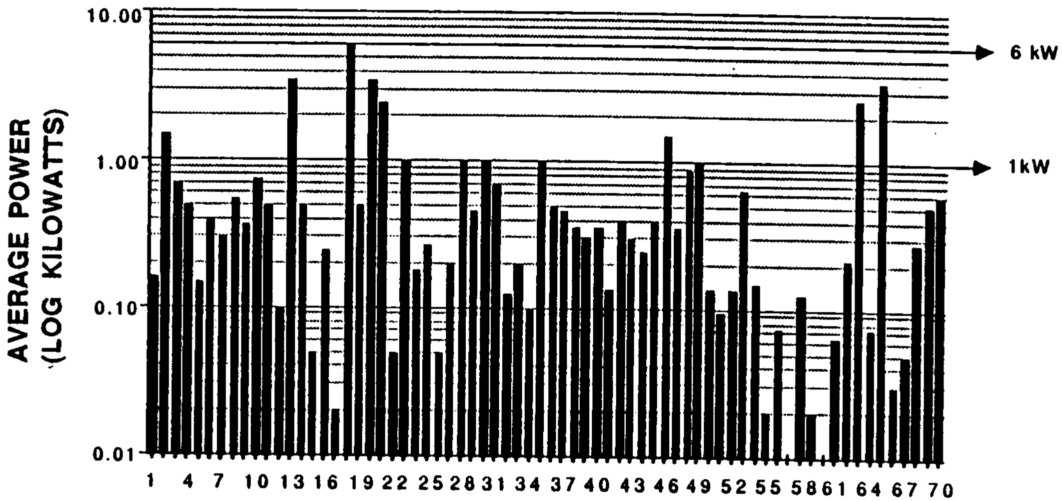
A summary of the RACO Study experiment power requirements are shown for both average and peak consumption. The Appendix B RFP established 7 kilowatts as the average power requirement which must be provided by the CDSF. As can be seen the large majority of the experiments require less than 800 watt average or peak. The RACO study combined experiment operational timelines and experiment run times to develop 7 KW as the maximum average power needed to accommodate mission sets based on the total 70 experiment set compliment.

In considering a reduced capability CDSF configuration, the RACO study was reviewed for a minimum set of requirements. For the mission scenario summaries listed, minimum average power requirements were between 2 to 4 kilowatts.

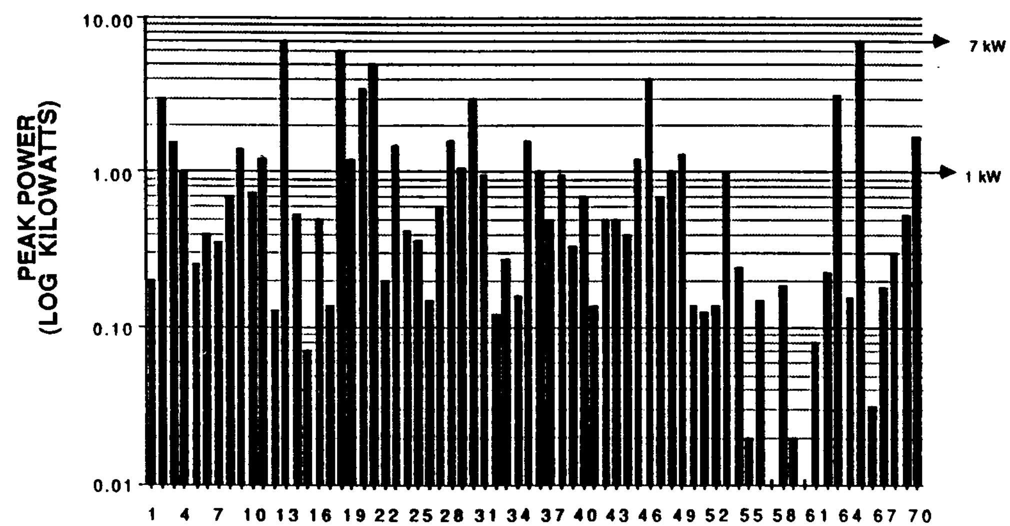
RACO STUDY POWER REQUIREMENTS SUMMARY

- **CDSF RFP REFERENCE**

USER ACTUAL AVERAGE POWER REQUIRMENTS



USER ACTUAL PEAK POWER REQUIREMENTS



RACO STUDY EXPERIMENT OPERATIONS SUMMARY

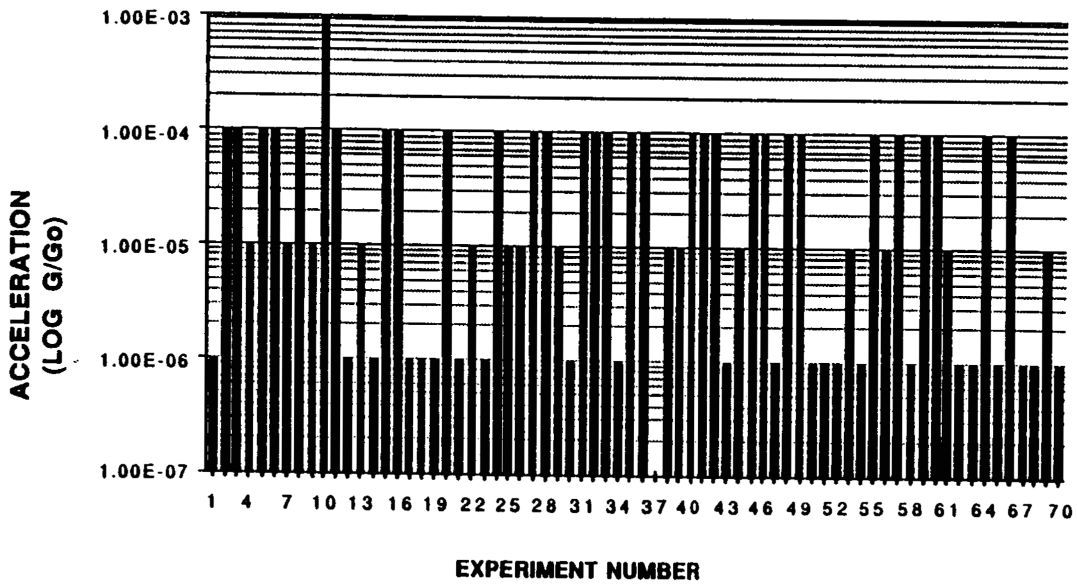
Two key factors for developing mission scenarios for CDSF configuration definition considerations are experiment run time and experiment acceleration requirements. While equipment operator requirements were not considered in any depth during the course of this in-house study, for the most part short experiment run times seem to be consistent with crew tended mission scenarios for reasons that include multiple sample runs, recalibration between runs and low power small sample size experimentation. 75% of the experiments listed in the RACO study have run times commensurate with extended duration orbiter missions of up to 25 days. 10 % of the experiments listed indicate run times in excess of 180 days.

Approximately 30% of the RACO study experiments require a one micro g operational environment. 7% of these experiments have operational run times that require a one micro g environment to be sustained for the Appendix B RFP requirement of 30 days or longer.

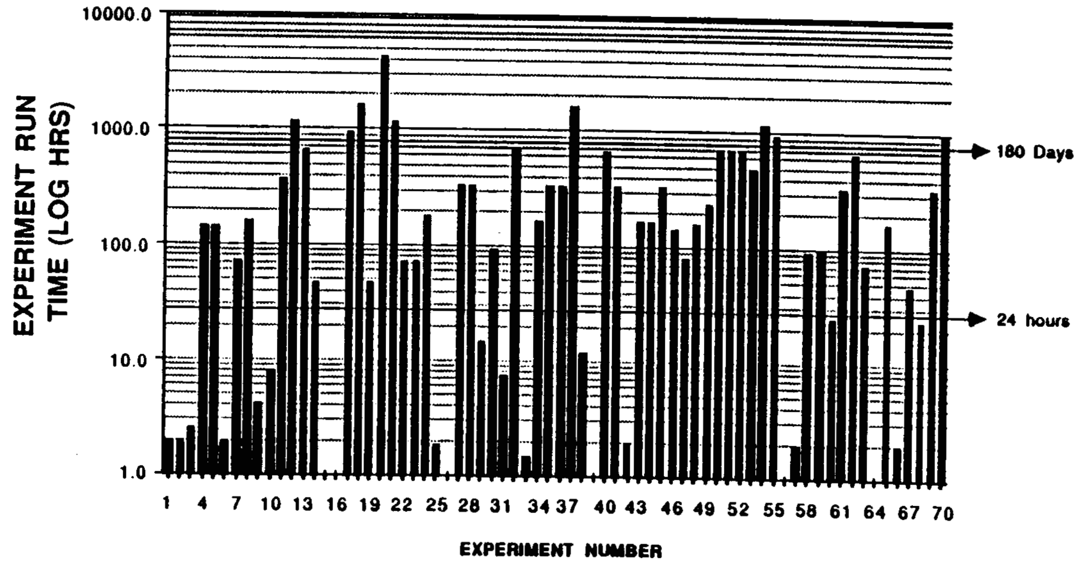
With one exception, all RACO experiments require acceleration levels of 100 micro g or less which is not achievable with current Space Shuttle flight mode characteristics. Approximately 20% of the RACO experiments have run time requirements on the order of 12 hours or less which can be accommodated with reasonable adjustments to Shuttle payload accommodations and flight mode characteristics which will be discussed in section 5.2.1 of this report. Approximately 55% of the listed experiments require 10 micro g or less acceleration levels which can only be attained in a free flying spacecraft mode. Free flier spacecraft characteristics for microgravity accommodation are presented in section 5.2.2 of this study.

RACO STUDY EXPERIMENT OPERATIONS SUMMARY

USER ACCELERATION REQUIREMENTS



USER RUN TIME REQUIREMENTS (per run)



COMMERCIALLY DEVELOPED SPACE MISSIONS

A review of the CDSF study references established these fundament objectives shown here for developing mission scenarios.

A key requirement was identified from the reference data with regard to configuration definitions to meet a one micro g acceleration environment. The need to maintain a ± 5 degree acceleration vector deviation from an initialized mean direction is major configuration definition constraint. It basically eliminates any consideration of free flier inertial flight modes except for experiments with extremely short duration run times on the order of a few seconds or less.

As previously mentioned, mission definitions that provide more stable crew tended flight modes are required and will be addressed in section 5.2.1 of this report. It appears that stable conditions for periods of about 12 hours are possible and provide a mission scenario that has at least a 55% experiment capture level.

The need for free flier mission scenarios is predicated on long duration experiment run time requirements and on a stable spacecraft definition that can provide acceleration levels of one micro g for the entire operational period. It also provides an evolutionary experiment carrier for development of future Space Station Freedom experiments which appear to require a high degree of autonomy to reduce the need for close human intervention for experiment operation.

Spacecraft power generation is a major configuration definition driver both in terms of on board system requirements and flight mode stability to achieve desired low microgravity acceleration levels and g vector direction stability for applications such as crystalline growth. The trade off between sample size, run time, power level acceleration environment are key microgravity experiment accommodation issues which must be taken into account in considering spacecraft concept definitions. For consideration of a reduced capability CDSF concept, both the RACO study mission scenarios and the current SPACELAB capability of 3 kilowatts for present microgravity experiment program development are judged to be minimum requirements for CDSF mission and configuration concept considerations.

COMMERCIALLY DEVELOPED SPACE FACILITY MISSIONS

SHOULD PROVIDE

- G–LEVEL OF 10 E–6 WHILE IN FREE–FLIGHT MODE
  (WITH LESS THAN ±5 DEGREE G VECTOR DEVIATION FROM MEAN)
- STABLE STS CREW–TENDED FLIGHT MODE
- "UNLIMITED" EXPERIMENT MISSION DURATION WHILE IN FREE–FLIGHT MODE
- AVERAGE MINIMUM POWER GREATER THAN 3 KW

NASA

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4.2.1. CANDIDATE EXPERIMENT IDENTIFICATION

CDSF STUDY CANDIDATE EXPERIMENT LIST

To support mission utilization definition task considerations for development of CDSF mission scenarios, experiment data sheets were generated from the in house study references listed in section 4.2 of this report. A summary listing is presented on the succeeding pages which has been developed from the latest knowledge of NASA space science and commercialization microgravity program development definitions.

The salient physical parameters are listed along with the NASA program office code which has development cognizance and an indication is provided for which quarter of the year it will be available for space flight consideration. The data rate column does not include experiment video requirements which is desired for free flier mission experiment candidates to permit interactive visual feedback for recalibration of the experiment before the next run. This is a concept configuration capability which will be addressed in section 9.0 of this report which describes mission control and data handling for CDSF missions.

This list of 35 experiments does not include hardware defined as outdated in the RACO study or any foreign experiments. Six Space Station Freedom (Code S) experiments are listed for reference and are not included for consideration in the 5 year CDSF mission scenario lease period. However, it is recognized that some development experiment subset could conceivably be considered for a CDSF follow on mission during the period from 1992 to 1997. Of the 14 Office of Space Science (Code E) experiments, 13 are currently defined for crew tended Space Shuttle SPACELAB type missions for which hardware rack mounting considerations must be provided for CDSF configuration definitions. Of the 15 Office of Commercial Programs (Code C) experiments, 10 require a free flier spacecraft or accommodation onboard the Freedom Space Station.

CDSF STUDY CANDIDATE EXPERIMENT LIST

EXPERIMENT DATA SHEETS FROM STUDY REFERENCES HAVE BEEN GENERATED THAT PROVIDE:

- A LISTING OF ALL CURRENTLY DEFINED MICROGRAVITY AND COMMERCIAL FLIGHT EXPERIMENT HARDWARE THAT MIGHT BE AVAILABLE FOR CDSF MISSIONS IN THE 1992 TO 1997 TIME PERIOD.

- SUMMARIZES KEY UTILITY REQUIREMENTS INCLUDING MICRO G LEVEL.

- AN INDICATION OF TIME PERIOD AVAILABLE FOR CDSF MISSION DEFINITION CONSIDERATION.

- A SHOPPING LIST FROM WHICH TO CHOOSE TYPICAL PAYLOAD SCENARIOS TO TEST THE CAPABILITIES OF THE TWO CDSF CONCEPTS DEFINED IN THIS STUDY.

- REVIEWED WITH CODE E/C PERSONNEL - 11/10/88

REVISED CDSF CANDIDATE EXPERIMENT LIST (1/89)

	EXPERIMENT HARDWARE	ACRONYM	VOLUME (CU. FT)	MASS (LBS)	RUNTIME (HRS)	DATA RATE (K BPS)	PWR-PK (KW)	PWR-AV (KW)	CODE	QTR AVAIL	MICRO G LEVEL
1	ACOUSTIC LEVITATION FACILITY	ALF	41.0	440	4 X 8	32.0	3.00	1.50	E	3Q - 92	<10
2	METALS & ALLOY SOLIDIFICATION APPARATUS	MASA	48.0	450	240	1.0	2.00	2.50	E	2Q - 91	<10
3	CRYSTAL GROWTH FURNACE	CGF	48.0	444	200	1.0	2.00	2.50	E	2Q - 91	1
4	DROP PHYSICS MODULE	DPM	41.0	993	2 X 28	1.0	<2.00	1.00	E	2Q - 91	<1
5	PROTEIN CRYSTAL GROWTH IV	PCG-IV	40.5	550	672	0.1	0.23	0.22	E		<10
6	SURFACE TENSION DRIVEN CONVECTION EXPERIMENT	STDCE	30.0	<5	48	0.1	<1.00	0.05	E	1Q - 91	<10
7	SOLID SURFACE COMBUSTION EXPERIMENT	SSCE	8.0	130	1	0.1	<1.00	0.08	E	2Q - 91	<10
8	MODULAR CONTAINERLESS PROCESSING FACILITY	MCPF	71.0	1764	336	50.0	4.40	3.00	S		<1
9	SPACE STATION FURNACE FAC.	SSFF	177.0	5954	24	48.0	37.00	17.00	S		<1
10	MODULAR COMBUSTION FAC.	MCF	71.0	1543	6		9.00	6.00	S		<1
11	FLUID PHYSICS DYNAMICS FAC.	FPDF	71.0	2426	8	50.0	10.00	6.00	S		<1
12	ADV. PROTEIN CRYSTAL GROWTH FACILITY	APCGF	71.0	551	24	0.5	1.00	0.35	S		<1
13	BIOTECHNOLOGY FACILITY	BTF	106.0	2315	24	5.0	5.00	1.75	S		<10
14	ADV. AUTOMATED DIRECTIONAL SOLID FUR.	AADSF	11.0	925	150	0.5	1.00	0.50	E	1Q - 91	<10
15	CRITICAL FLUID LIGHT SCATTERING EXPT.	CFLSE	20.0	<300	76-276	0.2	<1.00	0.75	E	2Q - 92	<10
16	DROPLET COMBUSTION EXPER.	DCE	6.0	152	6	0.1	<1.00	0.05	E	1Q - 92	<10
17	FLUIDS EXPERIMENT SYSTEM	FES	41.0	1084	192	20.0	2.00	0.98	E	2Q - 89	<10
18	ISOTHERMAL DENDRITE GROWTH EXPERIMENT	IDGE	32.0	700	65	1.5	<1.00	0.10	E	1Q - 91	<10

MN/C11

REVISED CDSF CANDIDATE EXPERIMENT LIST (1/89)
(CONT.)

	EXPERIMENT HARDWARE	ACRONYM	VOLUME (CU. FT)	MASS (LBS)	RUNTIME (HRS)	DATA RATE (K BPS)	PWR-PK (KW)	PWR-AV (KW)	CODE	QTR AVAIL	MICRO G LEVEL
19	LAMBDA POINT EXPERIMENT	LPE	41.00	1400	120	5.0	<1.00	0.45	E	1Q - 90	<100
20	VAPOR CRYSTAL GROWTH SYSTEM	VCGS	18.00	163	336	20.0	<1.00	0.52	E	2Q - 89	<10
21	CHEMICAL VAPOR TRANSPORT	CVT	40.50	440	72	1.0	0.35	0.30	C		
22	DIFFUSIVE MIXING OF ORGANIC SOLUTIONS	DMOS	6.12	188	1200	2.5	0.13	0.10	C		
23	DIRECTIONAL SOLIDIFICATION FURNACE	DSF	82.00	1200	672	3.0	7.00	3.50	C		
24	ELECTRODEPOSITION	EDEP	7.06	132	960	0.0	0.14	0.02	C		
25	ELECTROEPITAXIAL CRYSTAL GROWTH	ECG	40.00	1367	1680	2.0	6.00	6.00	C		
26	FLOAT ZONE CRYSTAL GROWTH FACILITY	FZCGF	4.30	295	1200	1.5	5.00	2.50	C		
27	FLUIDS EXPERIMENT APPARATUS	FEA	2.00	79	72	0.1	0.20	0.05	C		
28	NON-LINEAR OPTICAL MONOMERS	NLOM	9.71	209	720	0.0	0.14	0.14	C		
29	NON-LINEAR OPTICAL ORGANIC CRYSTALS	NLOOC	7.06	119	720	0.0	0.13	0.10	C		
30	NON-LINEAR OPTICAL THIN FILMS	NLOTF	9.71	209	720	0.0	0.14	0.14	C		
31	NORMAL FREEZING FURNACE	NFF	0.78	150	336	1.0	1.00	0.65	C		
32	ORGANIC SEPARATIONS	ORSEP	7.95	132	960	0.0	0.02	0.02	C		
33	PHY VAPOR TRANSPORT OF ORGANIC SOLIDS	PYTOS	6.53	376	96	2.5	0.19	0.13	C		
34	POLYMER MICROSTRUCTURE & MORPHOLOGY	PM3	4.33	200	100	0.5	0.02	0.02	C		
35	ZEOLITE CRYSTAL GROWTH	ZCG	18.00	400	1008	2.0	1.70	0.60	C		

MN/C12

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4.2.2. MISSION SCENARIOS

CDSF MISSION CATEGORIES

With the 6 Freedom experiments not being considered for initial CDSF missions, the remaining 29 experiments have experiment run times that can be categorized for 7 day Shuttle missions, 10 day STS OV-102 (Columbia) flights, 16 day extended duration orbiter flights, or free flier missions. The number of experiments captured for each flight is shown. These mission categories are based on run time only and no attempt was made during this in house study to develop mission scenarios based on many permutations and combinations of experiment compliments with repeated run times. Selected experiment combinations, however, were developed to test derived power and volume accommodation definitions.

For the mission scenarios developed, based on experiment run time, no mission category is defined for a 25 day EDO mission. However, experiment combinations could be conceived that define mission timelines requiring a 25 day STS EDO flight.

CDSF MISSION CATEGORIES

- **29 CANDIDATE EXPERIMENTS IDENTIFIED**
  - -- 6 ADDITIONAL SPACE STATION FOCUSED EXPERIMENTS COULD BE CONSIDERED
    - ACCOMMODATE WITH FOLLOW-ON CDSF RESUPPLY MISSIONS

- **7 DAY STS CREW TENDED MISSION**
  - -- 4.5 EXPERIMENT DAYS X 24 HR = 120 HR MAX RUN TIME
    - 11 CANDIDATE EXPERIMENTS

- **EXTENDED DURATION ORBITER CREW-TENDED MISSIONS**
  - -- 7 OV-102 EXPERIMENT DAYS X 24 = 168 HR
    - 12 CANDIDATE EXPERIMENTS
  - -- 16 DAY EDO EXPERIMENT DAYS X 24 HR = 384 HR
    - 18 CANDIDATE EXPERIMENTS
  - -- 25 DAY EDO EXPERIMENT DAYS X 24 HR = 600 HR MAX RUN TIME
    - 18 CANDIDATE EXPERIMENTS

- **FREE FLYER UNATTENDED MISSION**
  - -- 11 ADDITIONAL EXPERIMENTS WITH 28 TO 70 DAY RUN TIMES

EXPERIMENT PARAMETER SIZING CONSIDERATIONS FOR CANDIDATE CDSF MISSIONS

The 4 CDSF mission scenarios developed for this study are shown. While these mission categories were developed based on experiment run time, over a 5 year lease period they will capture 94% of the Appendix B RFP RACO study experiment definitions. Since the total experiment volume totals only about 500 cubic feet, an experiment volume of 300 cubic feet per mission would offer ample opportunity for reflights of various experiment combinations. At flight rates of 2 or 3 per year (6 or 4 month centers) experiment carrier volume capacity between 30 to 50 cubic feet per flight would provide 100% experiment capture over the 5 year period. Double that capacity would provide a minimum reflight capability for the same period.

The 16 day EDO mission is seen to have the highest power requirements. For a CDSF reduced capability concept, the Shuttle Orbiter power augmentation cryo kits can conceivably be considered to supply power demands over the 3.5 KW maximum average and 7.0 KW maximum peak requirements shown for the other mission models.

Candidate CDSF Missions
EXPERIMENT PARAMETER SIZING CONSIDERATIONS

- REPRESENTS 94% CAPTURE OF RFP REFERENCE EXPERIMENTS

TOTAL EXPERIMENT VOLUME ~500 FT^3

	MISSION	NUMBER OF EXPERI.	MAX DAYS RUNTIME	VOL (FT^3)	WT (LBS)	POWER (KW) AVG./PEAK
CREW TENDED MISSIONS	7 DAY STS	11	4	185	4116	1.3 / 3.0
	10 DAY STS	12	7	200	5441	2.5 / 4.2
	16 DAY STS/EDO	18	14	300	6254	6.2 / 7.6
	FREE FLYER	11	50	192	3435	3.5 / 7.0

- < 10 MICRO–G GENERALLY SPECIFIED FOR CREW TENDED MISSION SCENARIOS
  - DROP PHYSICS MODULE (DPM) ONLY EXPERIMENT REQUIRING < 1 μg
- FREE FLYER MISSIONS GENERALLY ACCOMMODATE LONG RUN TIME COMMERCIAL AND FREEDOM DEVELOPMENT HARDWARE

CDSF CAPABILITY REQUIREMENTS

The largest and smallest CDSF experiment carrier parameters are summarized based on the mission models generated. The largest requirement was derived from the 16 day EDO mission scenario. The smallest capability was derived from a doubling of volume requirements for a minimum reflight opportunity for each experiment over a 5 year lease period as previously mentioned.

CDSF CAPABILITY

- LARGEST PRACTICAL CDSF BASED ON EXPERIMENT HARDWARE LIST AND CDSF RFP
  - -- VOLUME = 300 FT^3
  - -- POWER = 7 KW AVERAGE

- SMALLEST PRACTICAL CDSF BASED ON EXPERIMENT HARDWARE LIST
  - -- VOLUME = 64 FT^3 (TWO DOUBLE RACKS)
  - -- POWER = ~ 3.0 KW AVERAGE

EXTENDED DURATION ORBITER INITIAL DEPLOYMENT FLIGHT CONSIDERATION

The 16 day extended duration orbiter mission scenario is seen to capture 61% of the candidate experiments established in this study. A CDSF experiment volume capacity of 300 cubic feet could accommodate such a mission. However, the Shuttle performance penalty for 16 day mission extension kits reduces the total payload mass to orbit by 8122 pounds which does not make it an attractive consideration as an initial deployment mission candidate. If utilization of the Shuttle Orbiter OV-102 vehicle must also be considered which reduces the up mass delivery capability in excess of 17,000 pounds, then only a reduced capability CDSF concept is seen as a viable consideration for such an initial deployment mission.

EDO INITIAL FLIGHT EXPERIMENT MANIFEST CONSIDERATION

- 16 DAY EDO MISSION AT 300 FT^3 EXPERIMENT VOLUME CAPTURES 61% OF CANDIDATE EXPERIMENTS FOR A SINGLE INITIAL MISSION

  -- NOT VIABLE FOR INITIAL LAUNCH

  -- 8122 LB EDO WEIGHT PENALTY TOO SEVERE FOR INITIAL MISSION

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5.0. EXPERIMENT ACCOMMODATION REQUIREMENTS

CDSF EXPERIMENT ACCOMMODATION REQUIREMENTS

This section of the CDSF study report defines the CDSF spacecraft resource and utility requirements established to accommodate candidate experiment list and the mission scenarios described in section 4.0

Analysis and assessments of desirable flight mode microgravity environments will be described for Shuttle attached crew tended missions and free flier missions.

CDSF EXPERIMENT ACCOMMODATION REQUIREMENTS

- RESOURCE AND UTILITY REQUIREMENTS
- FLIGHT MODE MICROGRAVITY ENVIRONMENT
  - SHUTTLE ATTACHED CREW-TENDED MISSIONS
  - FREE FLYER MISSION

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5.1. RESOURCE/UTILITY REQUIREMENTS

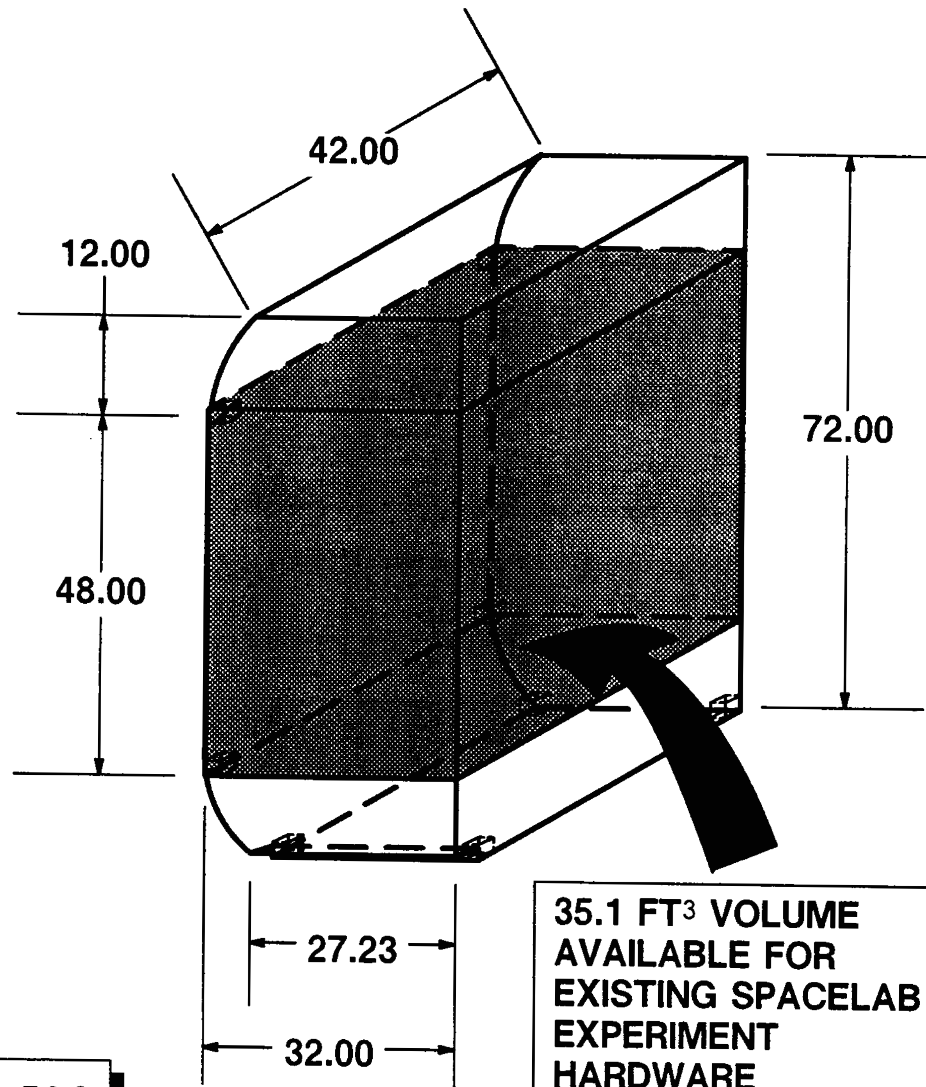
CDSF EXPERIMENT RACK SIZING

As a minimum the CDSF rack size must accommodate existing SPACELAB hardware as required by the Appendix B draft RFP. As will be described in section 6.0, the inside diameter of the CDSF is shorter than the inside diameter of the SPACELAB module due the need for structure to provide space effects shielding, thermal radiators and solar array packaging considerations. This results in a CDSF experiment rack 25 inches shorter than a SPACELAB rack. The minimum CDSF double rack established from layout studies performed is calculated to be able to accommodate at least 39 cubic feet of usable experiment equipment and at least 35 cubic feet of existing SPACELAB hardware as shown. For the total rack dimensions shown, 15 cubic feet of volume are allocated for experiment utility support which includes power, thermal, data and venting.

CDSF EXPERIMENT RACK SIZING

- **BASED ON SPACELAB DOUBLE RACK CONCEPT**
  - 25" SHORTER DUE TO CDSF INSIDE DIAMETER OF 10.5'
- **CAPABLE OF MOUNTING 17.425" WIDE BY 29.045" DEEP EXISTING SPACELAB EXPERIMENT HARDWARE (PER RFP)**
- **TOTAL EXPERIMENT WEIGHT PER RACK:**
  - 25 LB/FT^3 EXPERIMENT DENSITY (PER RFP)
  - WEIGHT = 25 LB/FT^3 x 39.2 FT^3 = 997.5 LBS/RACK

TOTAL VOLUME	=	54.2
INSTRUMENTATION/UTILITIES	=	-15.0
AVAILABLE EXPERIMENT VOLUME	=	39.2



35.1 FT^3 VOLUME AVAILABLE FOR EXISTING SPACELAB EXPERIMENT HARDWARE

rack

CDSF EXPERIMENT CAPABILITY

The key resource requirements for the 100% RFP CDSF reference capability concept and the reduced capability concept are summarized.

Based on layout considerations that will be described in section 6.0 and the mission scenarios developed in section 4.0 of this report, the experiment volume capacity is defined to be 320 cubic feet which represents 8 CDSF double racks as previously discussed. The 7 KW power capability is supports both by the RACO study mission sets and the CDSF mission scenarios defined in this study. For the derived CDSF mission scenarios with these concept configuration volume and power definitions, 97 % of the candidate experiments can be accommodated. The Code C Electroepitaxial Crystal Growth experiment which requires 6 KW average power for a continuous 70 day run time requires a special mission consideration.

The reduced capability concept, with a layout that allows 2 CDSF experiment racks, provide an experiment capacity defined to be 80 cubic feet. This volume capacity with no less than 3 KW of power available will accommodate 93% of the candidate CDSF experiment list for the mission scenarios defined with at least one re-flight opportunity over the 5 year lease period for each experiment.

CDSF EXPERIMENT CAPABILITY

- TOTAL VOLUME OF ALL 29 EXPERIMENTS IS ~ 500 FT^3

- TWO OF THE 29 EXPERIMENTS REQUIRE GREATER THAN 2.5 KW AVERAGE POWER DURING OPERATION

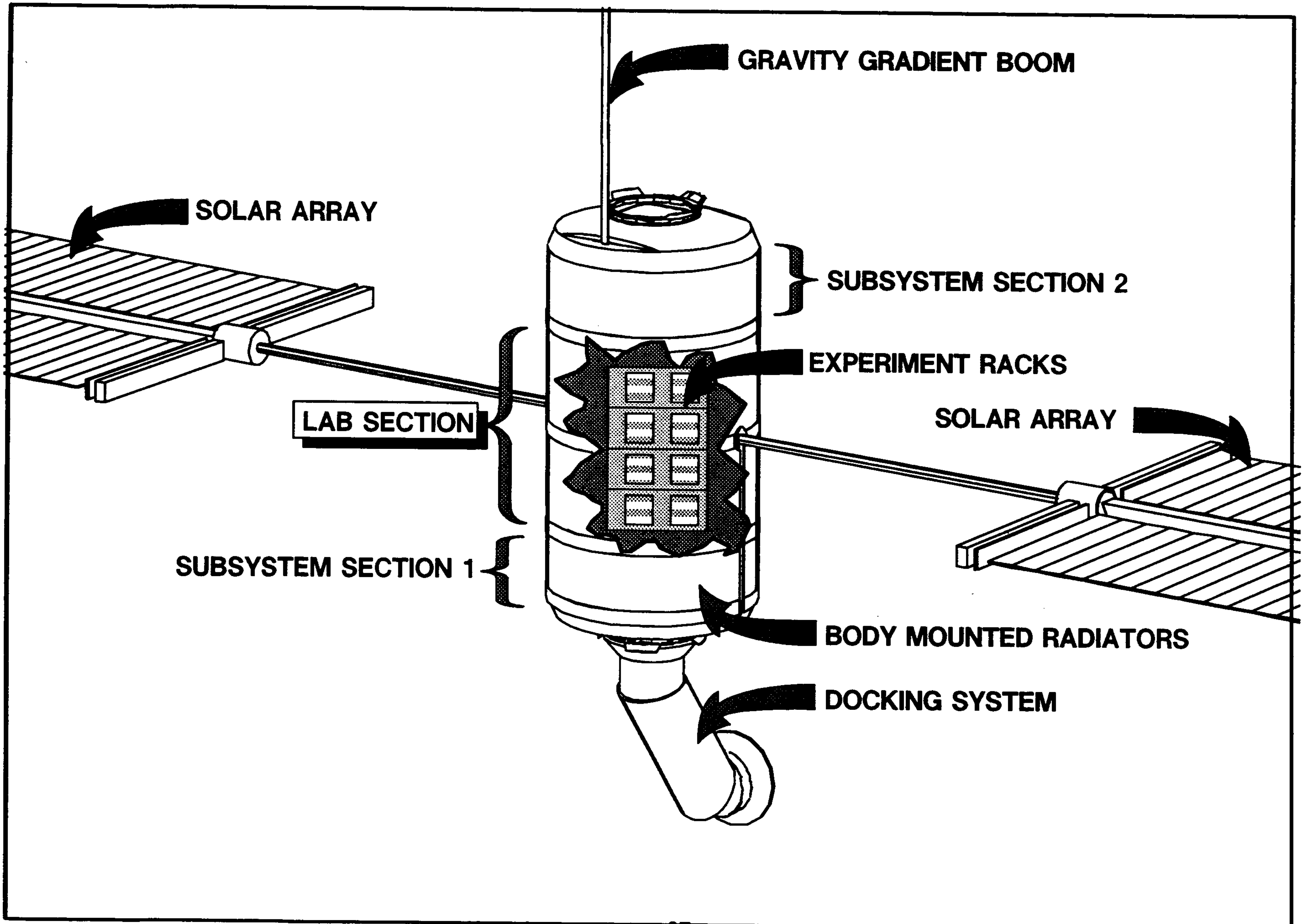
- CDSF PER RFP
  - AVERAGE POWER = 7.0 KW
  - EXPERIMENT VOLUME = 320 FT^3

- CDSF AT 20%
  - AVERAGE POWER REQUIRED IS ~ 3.0 KW
  - EXPERIMENT VOLUME SHOULD BE ~ 80 FT^3 (2 DOUBLE RACKS)
  - ACCOMMODATES ANY OF 27 EXPERIMENTS

CDSF PHYSICAL DESCRIPTION

The elements that make up the CDSF conceptual configuration are defined. The laboratory section is located in a position such that the vehicle center of mass is located in its center interior. As will be described in section 5.2, this location is ideal to achieve the lowest acceleration level possible during experiment operation. Two sections that accommodate spacecraft utility subsystems are located at each end of the facility. Photovoltaic solar arrays are defined for power generation. Body mounted radiators are defined for thermal energy heat dissipation. The gravity gradient boom is required to establish passive gravity gradient flight stability needed to achieve the required micro g levels for experiment accommodation as will be discussed in section 5.2. The docking system provides the pressurized interface to the Space Shuttle Orbiter for missions requiring shirt sleeve crew tended operations.

CDSF PHYSICAL DESCRIPTION



NASA

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5.2. FLIGHT MODE MICROGRAVITY ENVIRONMENT CONSIDERATIONS

NASA MICROGRAVITY SPACECRAFT ACCOMMODATION REQUIREMENTS

The primary accommodation requirement is to provide a microgravity environment to support a host of user defined low-g experiments onboard the CDSF while mated to the Shuttle Orbiter as well as when in a free-flyer mode

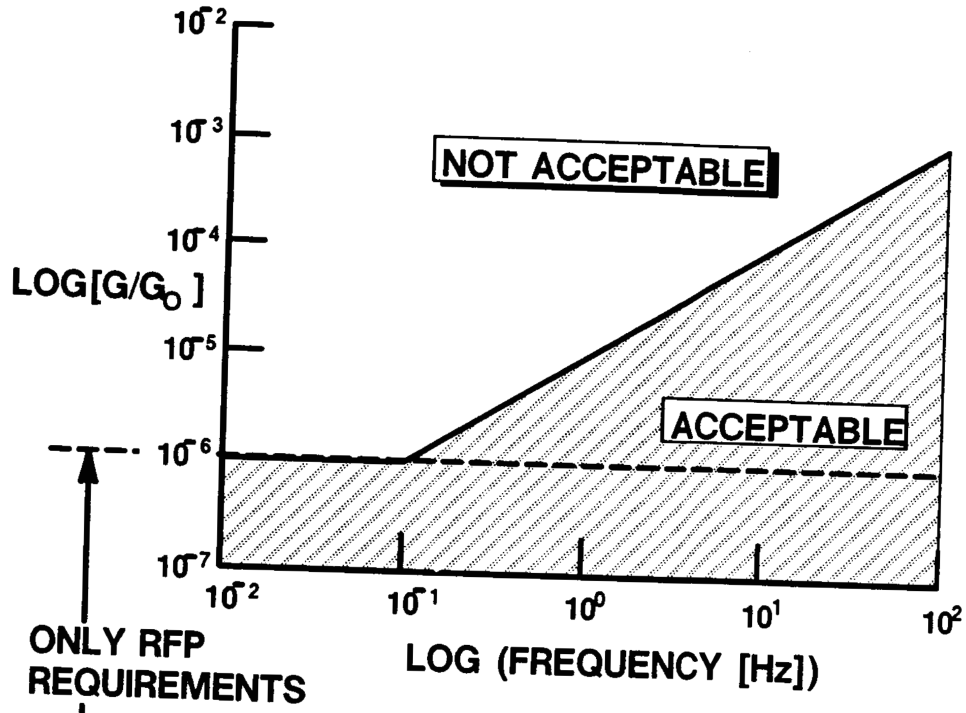
This section begins by discussing the micro-g requirements necessary to support the experiment community. Next, the steady state and dynamic sources of sensed acceleration are discussed. The impact of the attached CDSF orientation (which affects composite center of gravity location, and hence, micro-g environment) is discussed. Likewise, the impact of the large area solar arrays, which affect aerodynamic drag, and hence, sensed micro-g acceleration, is described. Examples of dynamic microgravity disturbances likely to be sensed by the CDSF are given. Because the mated attitude chosen for best supporting the CDSF microgravity environment is not defined as a standard shuttle Orbiter flight mode configuration orientation in NSTS 07700 Volume XIV standard payload Interface documentation, an assessment of the thermal environment for this flight attitude was performed to assure that thermal constraints were not exceeded. Finally, a study of the utilization of an Extended Duration Orbiter (EDO) to support CDSF is presented.

NASA microgravity magnitude and direction requirements as documented in the study References listed in Section 4.2 are shown here. The magnitude requirements are plotted vs frequency. A 1 Hz frequency disturbance can be as large as 10 micro-g's, whereas nearly constant disturbances are defined to be less than 1 micro-g.

The acceleration direction drawing shows the steady state components of acceleration sensed at a location on an Earth orbiting spacecraft. These components consist of aerodynamic drag deceleration, gravity gradient, and rotational acceleration due to angular velocity. The directional deviation requirement is defined to be less than plus or minus 5 degrees over the duration of an experiment.

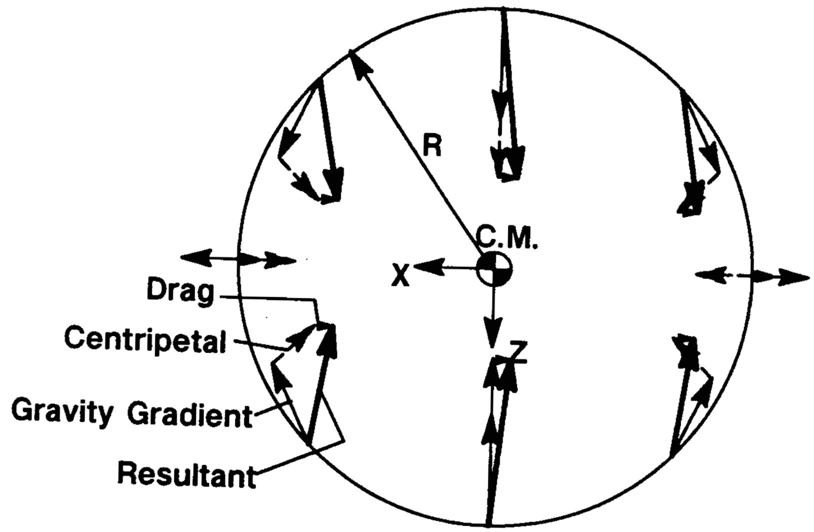
NASA MICROGRAVITY SPACECRAFT ACCOMMODATION REQUIREMENTS

ACCELERATION LEVEL



- 1 MICRO-G STEADY STATE
- INDUCED VIBRATION:
  $< 1 \times 10^{-6}$g for f < 0.1 Hz
  $< (1 \times 10^{-5} \times$ f)g for $0.1 <$ f < 100 Hz
  $< 1 \times 10^{-3}$g for f > 100 Hz

ACCELERATION DIRECTION



- NO GREATER THAN ±5 DEG

MGACCOMREQ

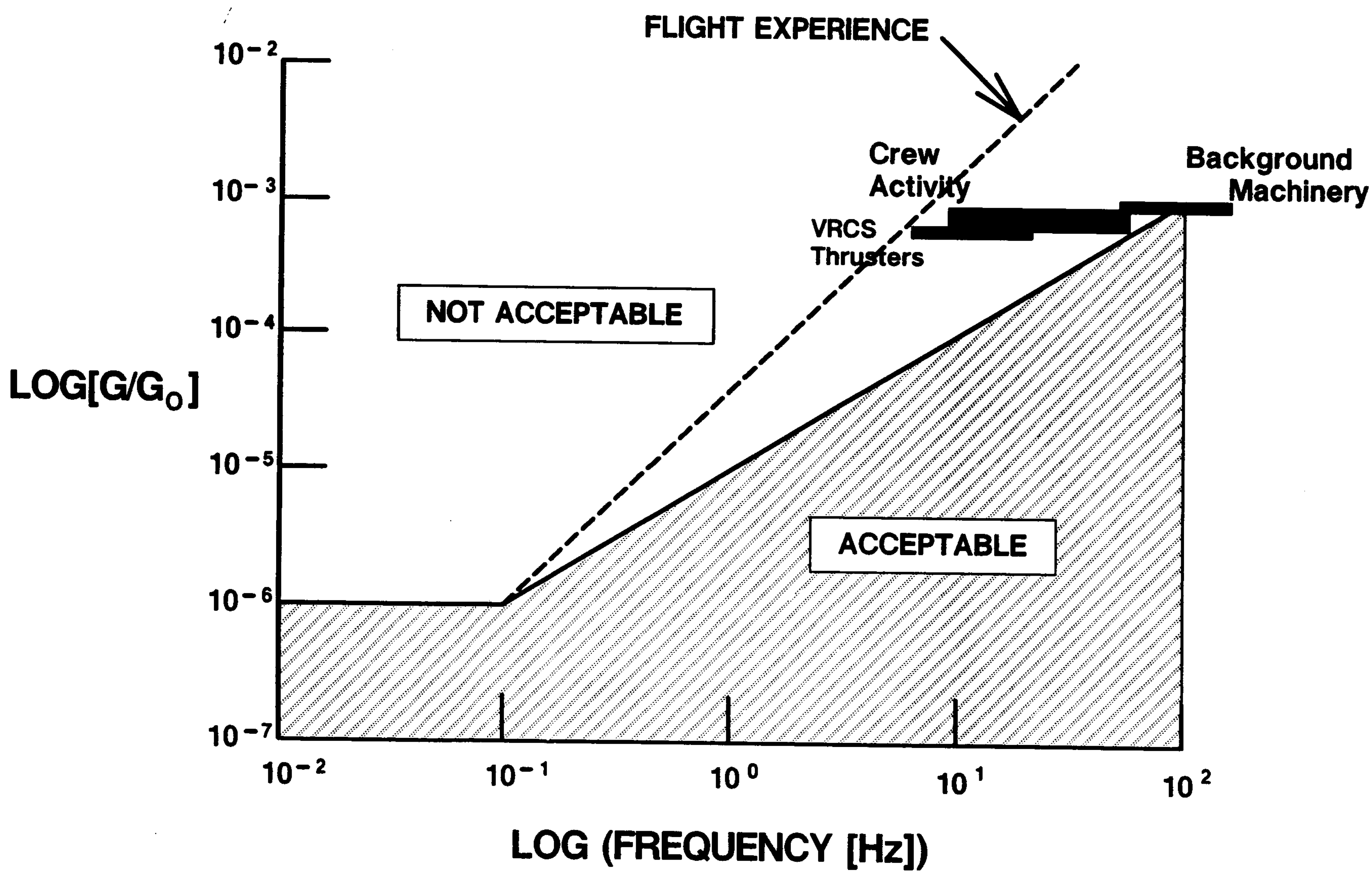
DYNAMIC MICROGRAVITY EXPERIMENT REQUIREMENTS

Actual NASA flight experienced onboard dynamic disturbances measured on previous STS microgravity experimentation missions (such as crew activity, vernier RCS attitude thrusting, and high frequency background machinery) are shown superimposed over the defined microgravity magnitude vs frequency requirements for comparison purposes. It can be seen that these disturbances generally fall outside of the acceptable magnitude requirements limit. The two dominant disturbances are vernier reaction control system (VRCS) thruster activity and crew activity.

VRCS thruster activity can be minimized by establishing more stable flight mode configuration geometry and attitude orientation. Analysis performed in this regard is presented in Section 5.2.1.1.

Crew activity disturbances is a condition of STS attached crew-tended operations. However, scheduling of experiments during periods of low crew activity together with implementation of passive flight mode stability techniques will be shown to provide several hours of low microgravity conditions within the defined steady state and dynamic limit requirements.

DYNAMIC MICROGRAVITY EXPERIMENT REQUIREMENTS



DYNMGREQ

NASA

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5.2.1. SHUTTLE ORBITER CREW-TENDED OPERATIONS

MAN-TENDED CDSF CONFIGURATIONS

Two man-tended CDSF configurations were analyzed for microgravity accommodation and passive flight mode stability assessment. The configuration shown on the left is one which attempts to align the center of mass of the CDSF as closely as possible to the center of mass of the Shuttle Orbiter. In the flight mode orientation shown, the CDSF is aligned parallel to the Orbiter cargo bay and perpendicular to the direction of the flight path. It's length is aligned along nadir or ''vertically" to the Earth's surface. A tunnel section is required between the CDSF and the docking system interface to achieve the desired configuration geometry.

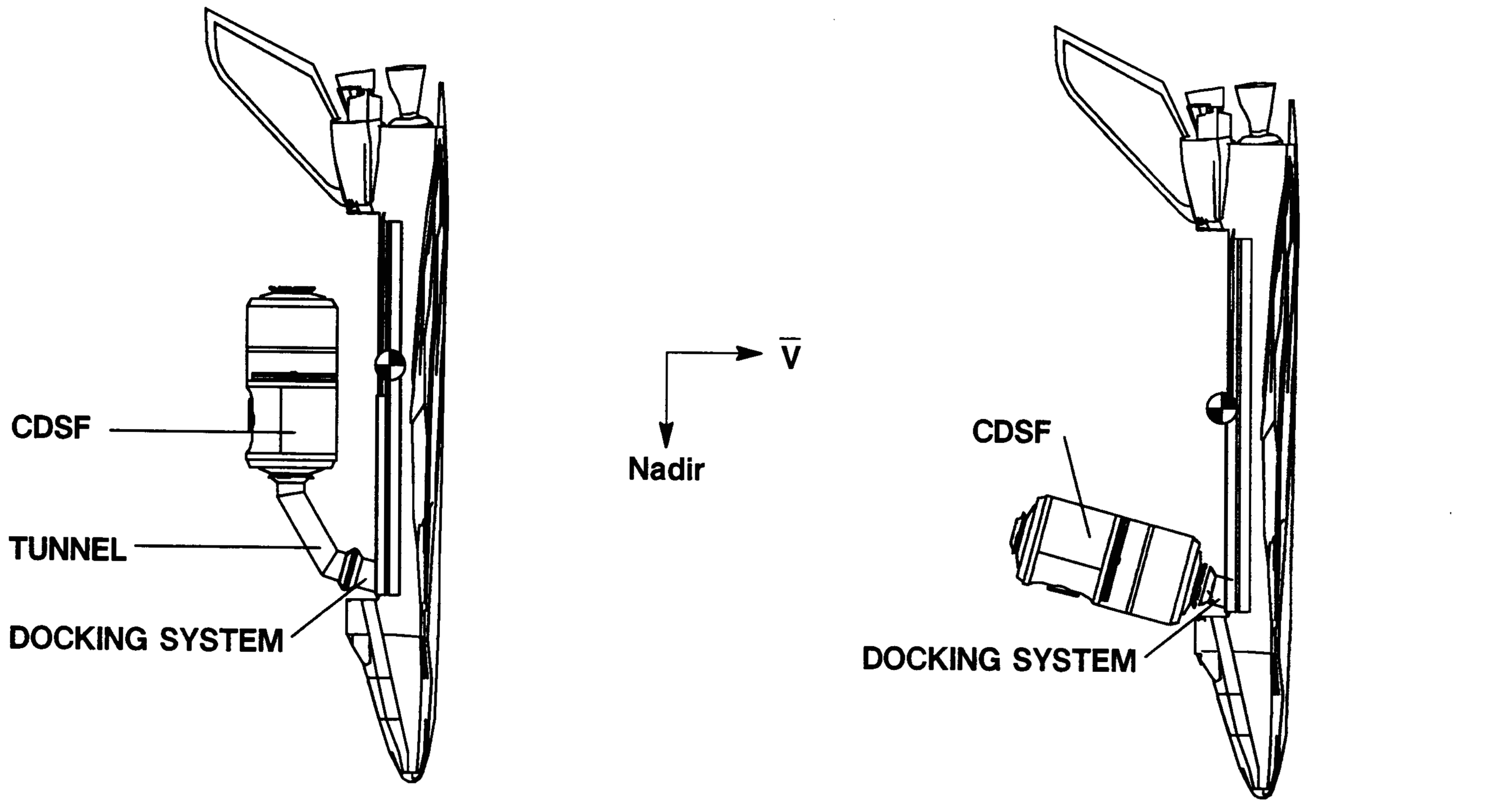
The configuration on the right shows the CDSF with it's length aligned along the direction of flight in an orientation ''horizontal" to the Earth's surface.

As will be shown, these two crew-tended configurations have very different microgravity environment characteristics.

MAN-TENDED CDSF CONFIGURATIONS

VERTICAL CONFIGURATION
CDSF BERTHED PARALLEL TO ORBITER

HORIZONTAL CONFIGURATION
CDSF BERTHED AT 75° ANGLE TO ORBITER



MTCDSFCONFIGS

CDSF CONFIGURATION PROPERTIES

The mass and inertias of the two candidate crew-tended configurations as well as the free flyer mass properties were computed based on the following assumptions :

1 - solar array sized for 7 kW average power

2 - maximum STS up mass of 40,030 lbs to 220 Nm

3 - CDSF, solar array, and docking mass distribution within STS abort landing C.G. constraints.

This yielded a CDSF mass of 13,610 Kg. The ''vertical'' configuration weighs an additional 900 Kg due to the required tunnel. The combined CDSF/Orbiter weight is about 108,000 Kg (238,000 lb).

C-2

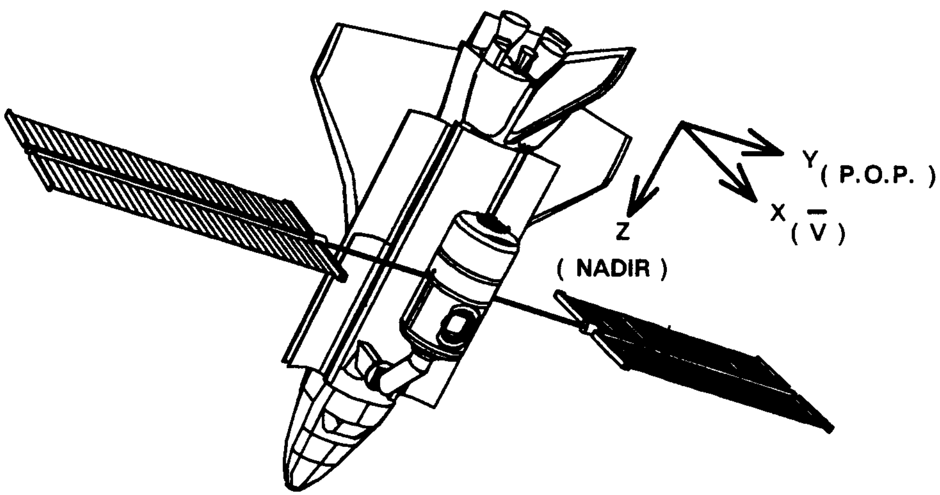
CDSF CONFIGURATION PROPERTIES

VERTICAL CONFIGURATION

MATED CONFIGURATION

TOTAL MASS = 108,600 KG

IXX = 1.051E7 KG*M**2   IYY = 1.019E7 KG*M**2
IZZ = 1.996E6 KG*M**2   IXY = -1243 KG*M**2
IXZ = 4.761E5 KG*M**2   IYZ = -3563 KG*M**2



CDSF FREEFLYER

TOTAL MASS = 14,510 KG

IXX = 6.647E5 KG*M**2   IYY = 3.954E5 KG*M**2
IZZ = 3.144E5 KG*M**2   IXY = -209 KG*M**2
IXZ = -1.784E4 KG*M**2   IYZ = 9.25 KG*M**2

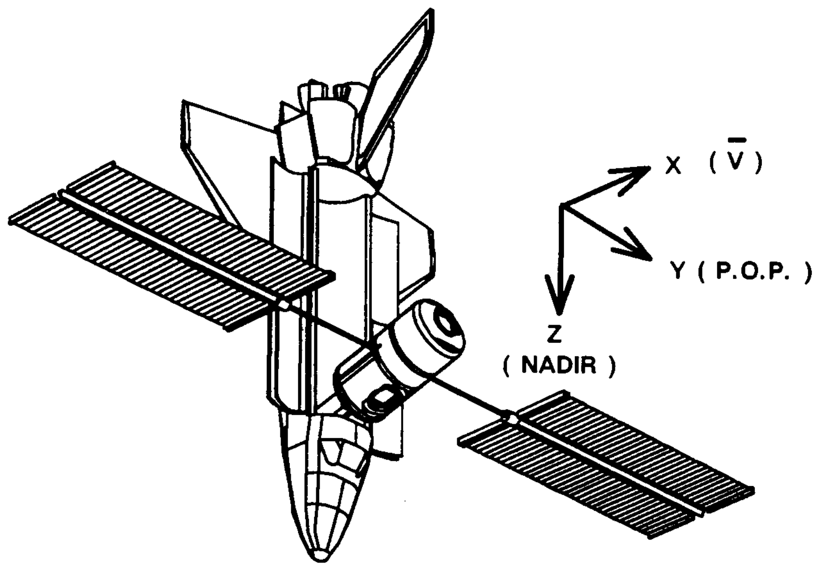
MASS PROPERTIES INCLUDE
GRAVITY GRADIENT BOOM

HORIZONTAL CONFIGURATION

MATED CONFIGURATION

TOTAL MASS = 107,770 KG

IXX = 1.121E7 KG*M**2   IYY = 1.126E7 KG*M**2
IZZ = 2.368E6 KG*M**2   IXY = -1137 KG*M**2
IXZ = 1.109E6 KG*M**2   IYZ = -3893 KG*M**2



CDSF FREEFLYER

TOTAL MASS = 13,610 KG

IXX = 6.580E5 KG*M**2   IYY = 9.284E5 KG*M**2
IZZ = 3.117E5 KG*M**2   IXY = 200 KG*M**2
IXZ = 9.531E3 KG*M**2   IYZ = -143 KG*M**2

MASS PROPERTIES INCLUDE
GRAVITY GRADIENT BOOM

BOTH

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5.2.1.1. STEADY STATE PASSIVE STABILIZATION

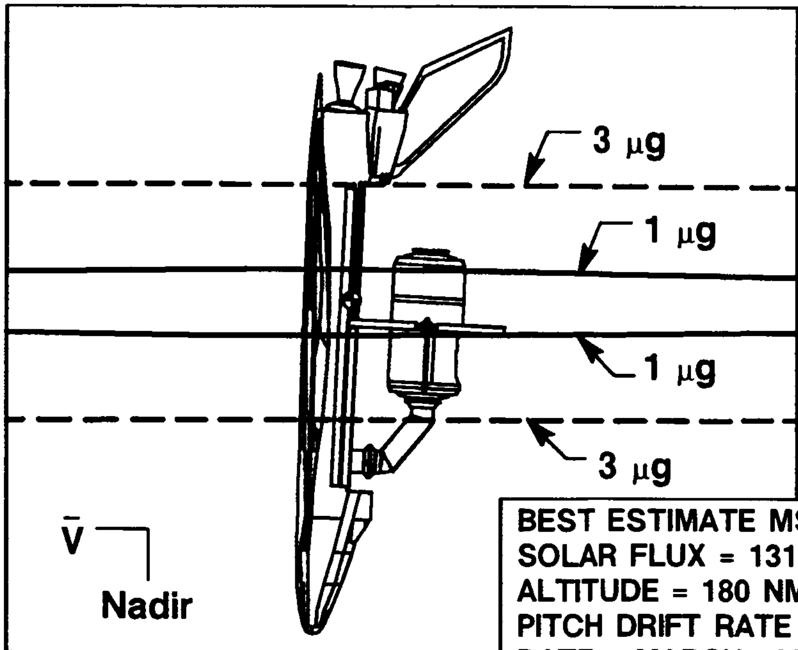
TWO CREW TENDED CDSF CONFIGURATION OPTIONS STUDIED

An analysis was performed to determine the steady state microgravity environment for the two previously described CDSF crew-tended configurations. Sensed acceleration levels with respect to the center of mass of the composite STS/CDSF configuration are shown as contour lines superimposed over the two configurations. Due to the composite center of gravity offset, the horizontal configuration only fell within the 5 micro-g contour, whereas the vertical configuration lab section fell within the 1 micro-g region.

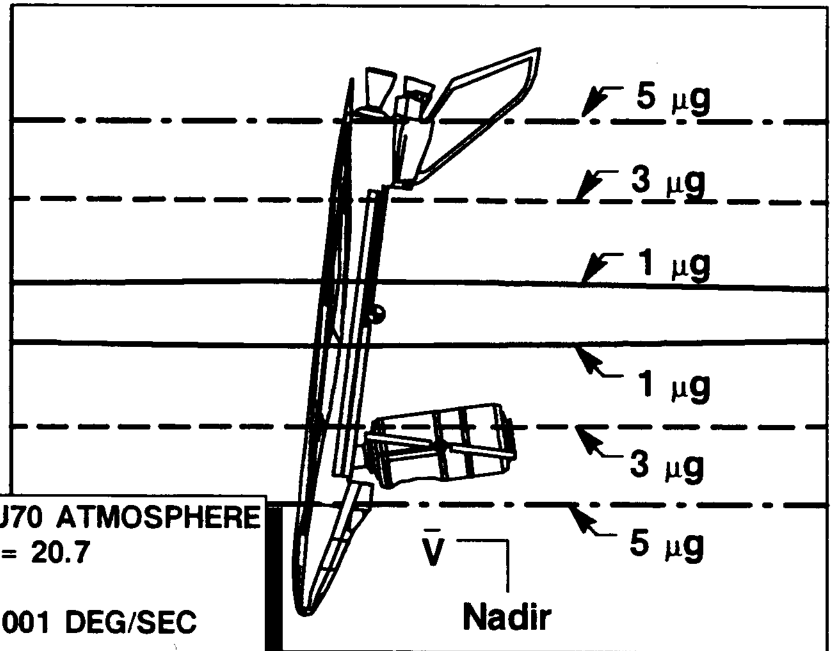
TWO CREW TENDED CDSF CONFIGURATION OPTIONS STUDIED

- GRAVITY GRADIENT ASSISTED ATTITUDE STABILIZATION

ONE MICRO-G OPTION



< 5 MICRO-G OPTION



BEST ESTIMATE MSFC/J70 ATMOSPHERE
SOLAR FLUX = 131, AP = 20.7
ALTITUDE = 180 NMI
PITCH DRIFT RATE = ±0.001 DEG/SEC
DATE = MARCH 1993

- BEST CASE MICRO-G ACCOMMODATION
  - ONE MICRO-G COST DELTA GENERATION
- WORST CASE STABILITY ANALYSIS
- NORMALIZED COST ANALYSIS AND COMPARISONS

VALIDATION CHECK CASES AGAINST MISSION UTILIZATION DEFINITION SCENARIOS

CDSF/ORBITER MATED CONFIGURATION CHARACTERISTICS

For the crew-tended configuration options studied, the horizontal steady state sensed acceleration was found to exceed 3 micro-g's, whereas the vertical met the 1 micro-g requirement. The microgravity vector direction variation over an orbit met the plus or minus 5 degree variation requirement for the horizontal configuration, while the vertical configuration varied by up to 10 degrees below 200 Nm. The vertical free-flyer microgravity environment is similar to the mated vertical configuration microgravity environment; the horizontal free-flyer environment differs from the horizontal mated micro-g environment. The mated horizontal configuration is passively stable, and does not require any active attitude control devices; the vertical configuration is not passively stable. The vertical configuration required a tunnel to fall within the most favorable micro-g region. The horizontal configuration did not require a tunnel.

CDSF/ORBITER MATED CONFIGURATION CHARACTERISTICS

HORIZONTAL CONFIGURATION	VERTICAL CONFIGURATION
1 MICRO–G MAGNITUDE EXCEEDED (3 MICRO–G)	1 MICRO–G MAGNITUDE MET
+/– 5 DEG MICRO–G DIRECTION REQ'T MET	+/– 5 DEG MICRO–G DIRECTION REQ'T EXCEEDED (5 – 10 DEG)
DIFFERENT MICRO–G ENVIRONMENT COMPARED TO FREE FLYER	SIMILAR MICRO–G ENVIRONMENT COMPARED TO FREE FLYER
STABLE	REQUIRES MOMENTUM WHEEL OR CMGs FOR STABILITY
NO TUNNEL REQUIRED	TUNNEL REQUIRED

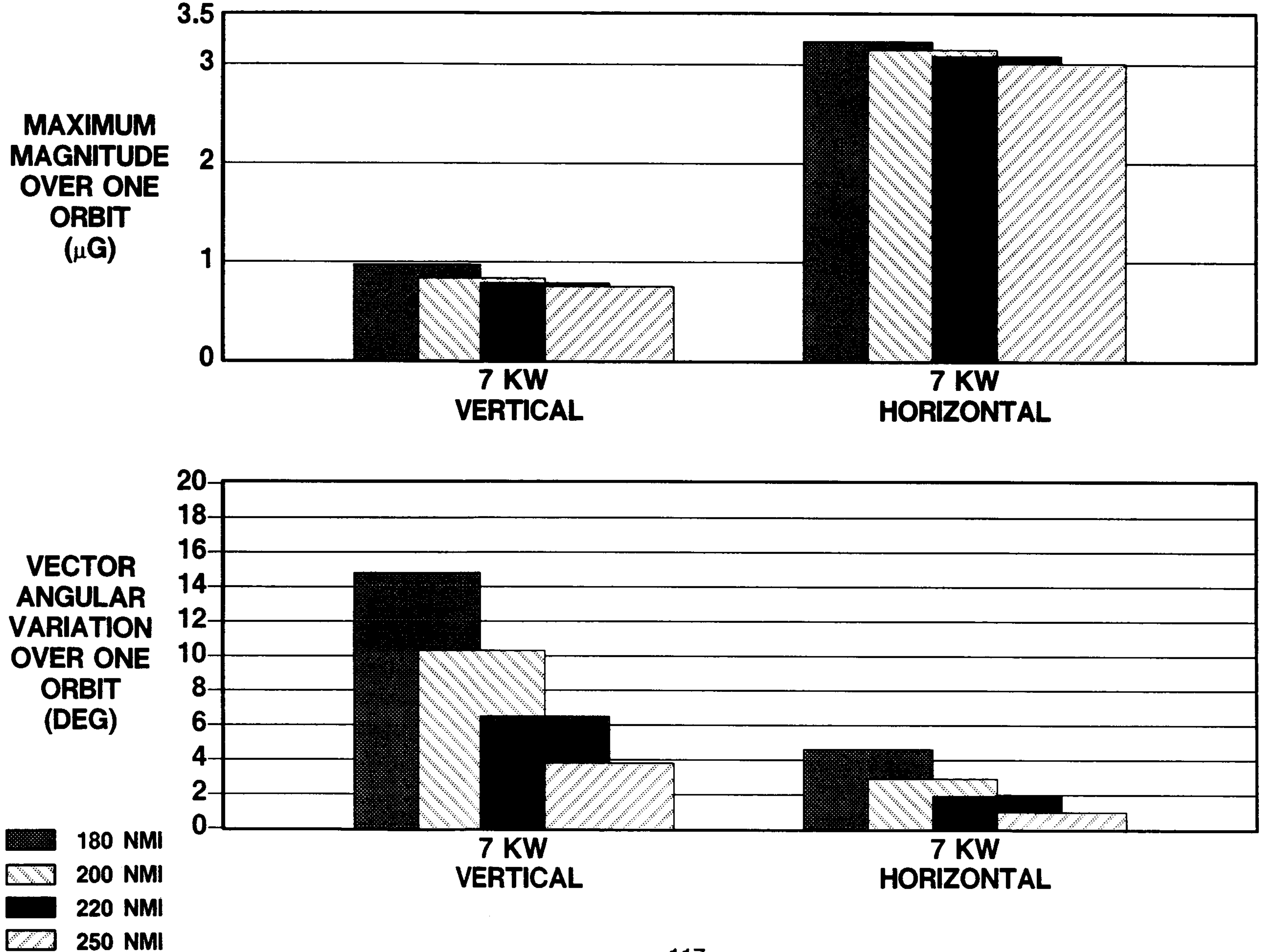
STEADY STATE MICROGRAVITY CDSF MATED TO ORBITER CONFIGURATIONS

An analysis was performed to determine the sensitivity of the micro-g magnitude and direction to variations in altitude. The upper bar graph depicts the maximum micro-g magnitude sensed at the CDSF lab section over one orbit for the mated horizontal and vertical configurations studied at various altitudes. Note that the horizontal configuration exceeds 3 micro-g's, whereas the vertical is just under 1 micro-g. As can be seen, this variation is relatively insensitive to altitude over the 180 to 250 Nm altitude regime studied.

The lower bar graph shows the variation in micro-g direction over an orbit. The horizontal mated configuration varies by less than 5 degrees over all altitudes studied. The vertical mated configuration varies by 4 degrees at high altitudes (e.g., 250 Nm), but varies by up to 15 degrees at low altitudes (180 Nm)

Thus, considering the two mated configurations studied, the vertical configuration met the 1 micro-g requirement, but not the plus or minus 5 degree directional variation requirement. On the other hand, the horizontal configuration met the 5 degree direction requirement, but suffered from a 3 micro-g magnitude.

Steady State Microgravity
CDSF MATED TO ORBITER CONFIGURATIONS



posgenmate

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5.2.1.2. DYNAMIC DISTURBANCE ASSESSMENT

STS DYNAMIC ENVIRONMENT

The dynamic acceleration environment of the CDSF while mated to the Orbiter is affected by Orbiter attitude re-orientation, Orbiter propulsive venting, and crew motion. Orbiter attitude re-orientation is required for star tracker alignment and may be required to satisfy thermal constraints. Attitude maneuvers adversely impact the dynamic acceleration environment of the CDSF while mated to the orbiter. A 1 deg/sec STS rotation can induce a sensed acceleration within the CDSF greater than 100 micro-g.

Orbiter propulsive venting occurs daily but can be scheduled around sensitive microgravity experiment operation. A 1 lb propulsive vent induces a sensed acceleration within the CDSF of 4 micro-g.

Crew motion has an adverse impact on the dynamic acceleration environment within the CDSF. Un-isolated crew exercise with the treadmill induces a sensed acceleration of 2100 micro-g at 2.9 Hz within the CDSF. A crew push-off of 25 lb to accelerate a crew person to 2.7 ft/sec induces a sensed acceleration of 100 micro-g within the CDSF.

STS DYNAMIC ENVIRONMENT

WHILE MATED TO THE CDSF

STAR TRACKER ALIGNMENT REQUIRES ORBITER ATTITUDE REORIENTATION TWICE A DAY MINIMUM

PROPULSIVE VENTS OCCUR DAILY BUT CAN BE SCHEDULED; HOWEVER, ATTITUDE REORIENTATION MAY BE REQUIRED TO MAINTAIN PROPER NOZZLE TEMPERATURES. ADDITIONAL THERMAL CONSTRAINTS SUCH AS WINDOW GASKET TEMPERATURES MIGHT ALSO REQUIRE ATTITUDE REORIENTATION

NOTE : A ONE (1) LB PROPULSIVE VENT INDUCES A 4 MICRO–G SENSED ACCELERATION WITHIN CDSF

A ONE (1) DEG/SEC ROTATION RATE INDUCES > 100 MICRO–G SENSED ACCELERATION WITHIN CDSF

VARIOUS CREW INDUCED MOTIONS:

TREADMILL (un–isolated) 2100 micro–g (2.88 Hz)

PUSHOFF 25 Lb = 2.7 ft/sec = 100 micro–g

2.5 Lb = 16 ft/min = 10 micro–g (step impulse)

ORBITER / CDSF ATTITUDE STABILITY

Both the Orbiter only and the Orbiter with CDSF can fly in a gravity gradient stable attitude. The Orbiter VRCS is capable of damping a pitch attitude rate error to acquire the gravity gradient stable attitude.

Computer simulations were validated by simulating STS-4 flight orientation performance in a gravity gradient stable mode (Orbiter nose down, 45 deg roll flight orientation). A 1 deg/sec pitch error was controlled to ± 1 deg within 1 orbit with Orbiter VRCS. The Orbiter subsequently exhibited an attitude stability of ± 8 deg with no VRCS control.

Similarly, the CDSF vertical crew tended configuration with arrays trailing in a -Vbar direction mated to the Orbiter was simulated in a gravity gradient stable flight attitude (Orbiter nose down, underside tiles in the direction of the flight path). A 1 deg/sec pitch error was controlled to ± 1 deg within 1 orbit with Orbiter VRCS. The Orbiter with CDSF subsequently exhibited an attitude stability of ± 1 deg with no VRCS control.

ORBITER / CDSF ATTITUDE STABILITY

ORBITER VRCS (1 lb–sec min impulse bit) CAPABLE OF DAMPING PITCH ATTITUDE RATE ERROR IN STABILITY REGION

ORBITER ONLY NOSE DOWN AT TEA (STS–4 FLIGHT ORIENTATION)

1 deg/sec pitch error, 1 deg deadband VRCS control
- Controlled to ±1 deg within 1 orbit
- Attitude stability ±8 deg (no VRCS control)

ORBITER/CDSF NOSE DOWN, UNDERSIDE TILES IN DIRECTION OF FLIGHT PATH

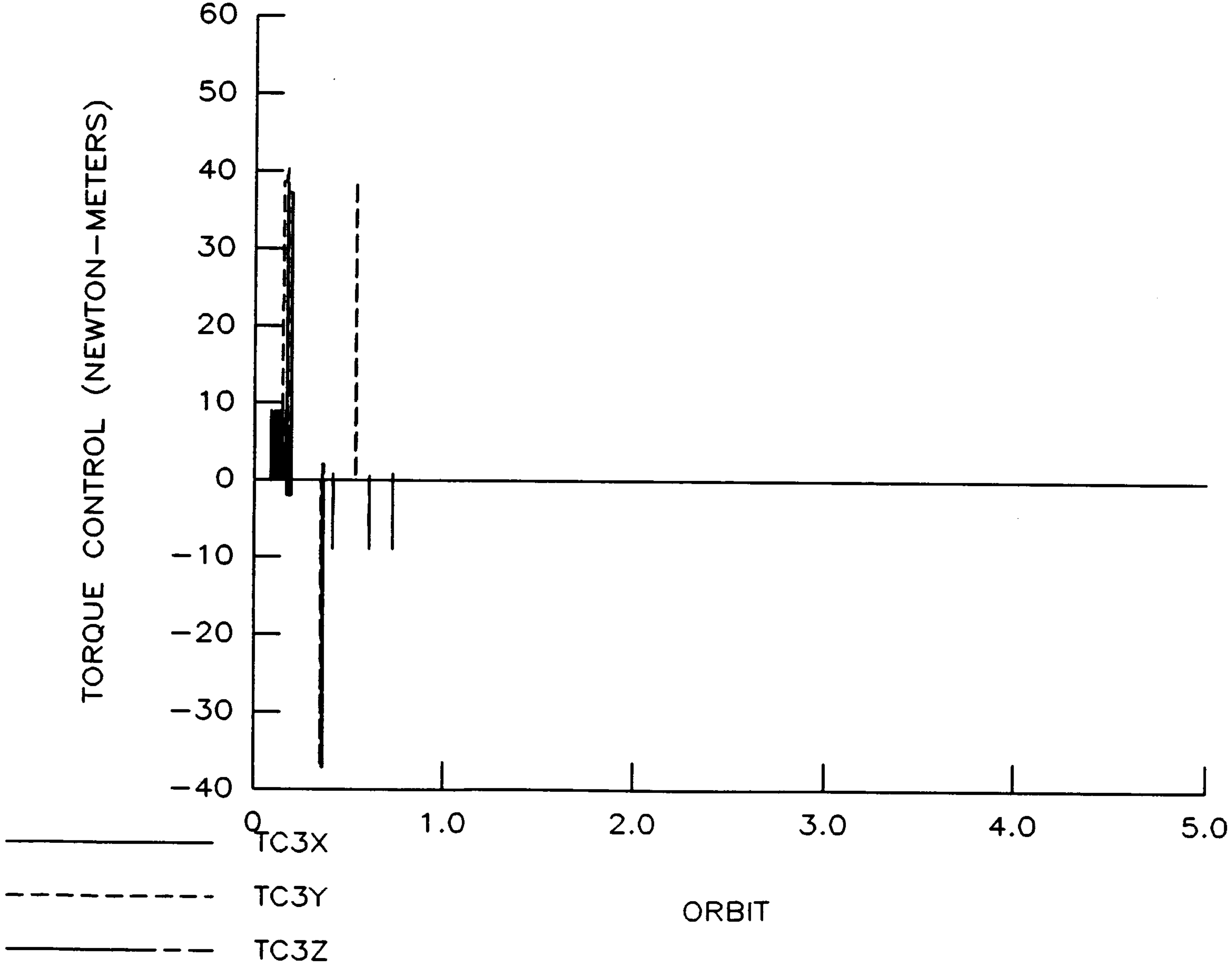
1 deg/sec pitch error, 1 deg deadband VRCS control
- Controlled to ±1 deg within 1 orbit
- Attitude stability ±1 deg (no VRCS control)

ORBITER ONLY, VRCS CONTROL

The ability of the Orbiter to attain a passive gravity gradient flight mode orientation is illustrated by this plot of control torques over a five orbit period. An initial attitude rate error of 1 degree/second was set as initial conditions for the pitch channel for this simulation. The control torque activity in the initial orbit is due to VRCS activity to damp out this initial rate error. Once the initial pitch attitude rate error of 1 degree/second was damped out in the first orbit, vernier jet firing was inhibited. The vehicle remained in a stable flight mode for the remainder of the simulation as will be shown on the following page.

plot1

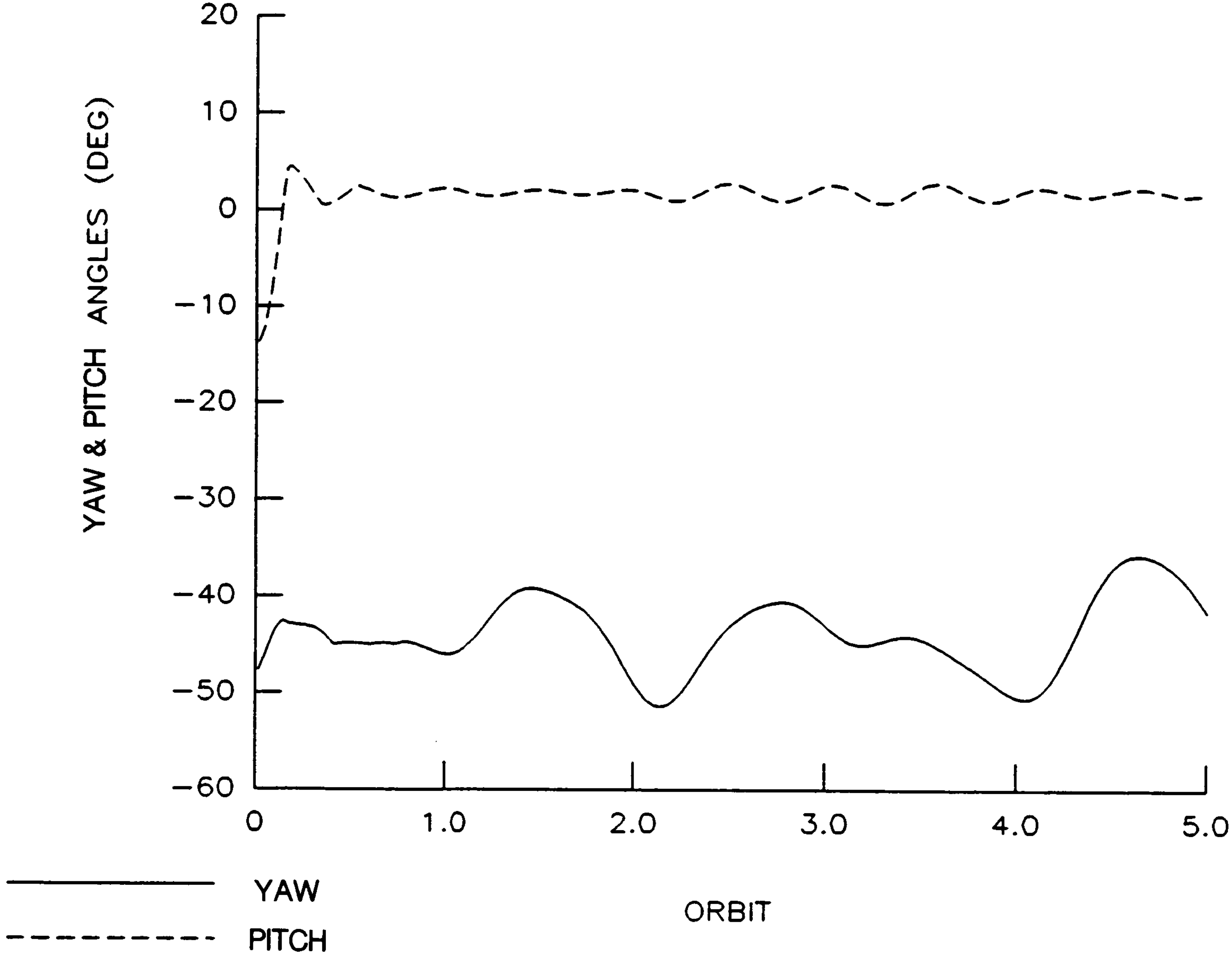
TORQUE CONTROL VS TRUE ANOMALY
ORBITER NOSE DOWN, AT TEA



ORBITER ONLY, ATTITUDE STABILITY

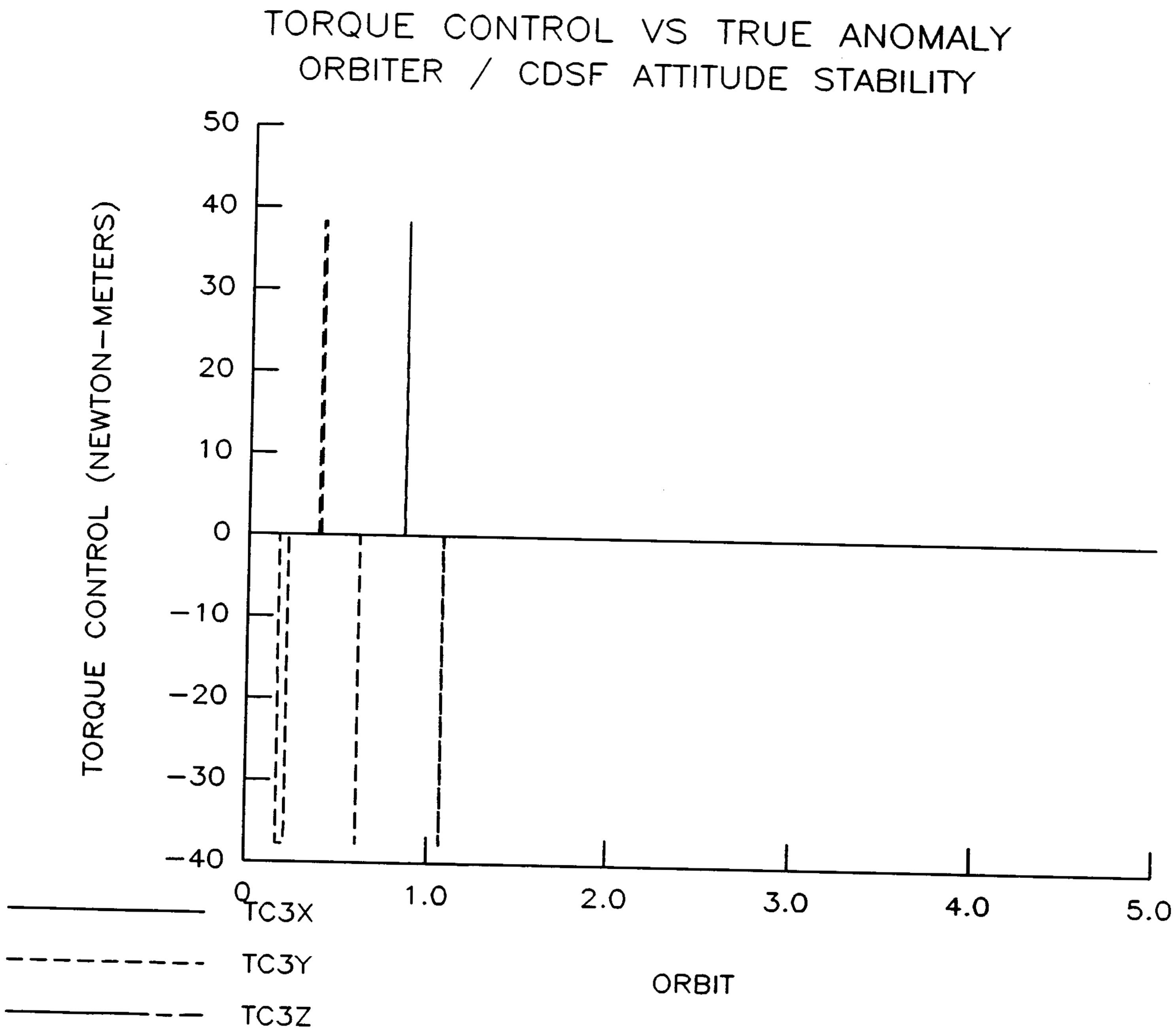
The ability of the Orbiter to attain a gravity gradient stable flight orientation is illustrated in this plot of yaw and pitch attitude over five orbits. The simulation starts at the end of the first VRCS jet firing. Once the initial pitch attitude rate error of 1 deg/sec has been damped and the vernier jets are inhibited as illustrated on the previous page, the Orbiter exhibits an attitude stability of ± 8 deg in a nose down, 45 deg roll flight orientation.

YAW AND PITCH ANGLES VS TRUE ANOMALY
ORBITER NOSE DOWN, AT TEA



ORBITER / CDSF, VRCS CONTROL

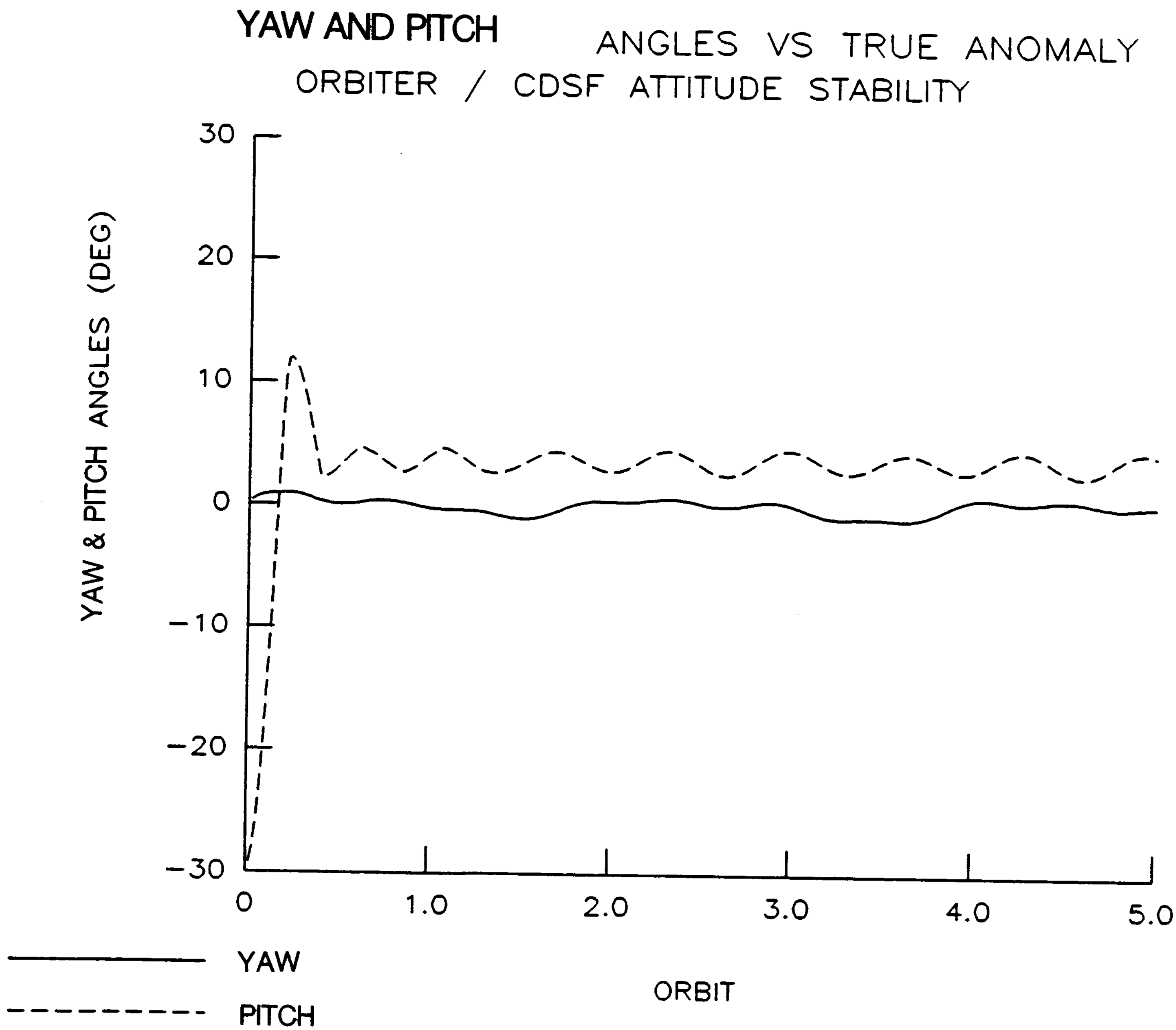
The ability of the Orbiter with the CDSF attached to attain a passive gravity gradient flight mode orientation is illustrated by this plot of control torques over a five orbit period. An initial attitude rate error of 1 degree/second was set as initial conditions for the pitch channel for this simulation. The control torque activity in the initial orbit is due to VRCS activity to damp out this initial rate error. As can be seen in the following pages, it took just over one orbit to damp out the initial pitch attitude rate error of 1 degree/second and assume a passively stable gravity gradient orientation which required no VRCS jet firing activity.



TORQUE CONTROL VS TRUE ANOMALY
ORBITER / CDSF ATTITUDE STABILITY
TORQUE CONTROL (NEWTON-METERS)
50
40
30
20
10
0
-10
-20
-30
-40
0
1.0
2.0
3.0
4.0
5.0
ORBIT
TC3X
TC3Y
TC3Z

ORBITER / CDSF, ATTITUDE STABILITY

This plot illustrates the Orbiter with CDSF yaw and pitch attitude stability time history over 5 orbits. The simulation starts at the end of the first VRCS jet fire. Once the initial pitch attitude rate error of 1 deg/sec has been damped and the vernier jets are inhibited as illustrated on the previous page, the Orbiter with CDSF exhibits an attitude stability of ± 1 deg in a nose down, underside tiles in direction of flight path flight orientation.

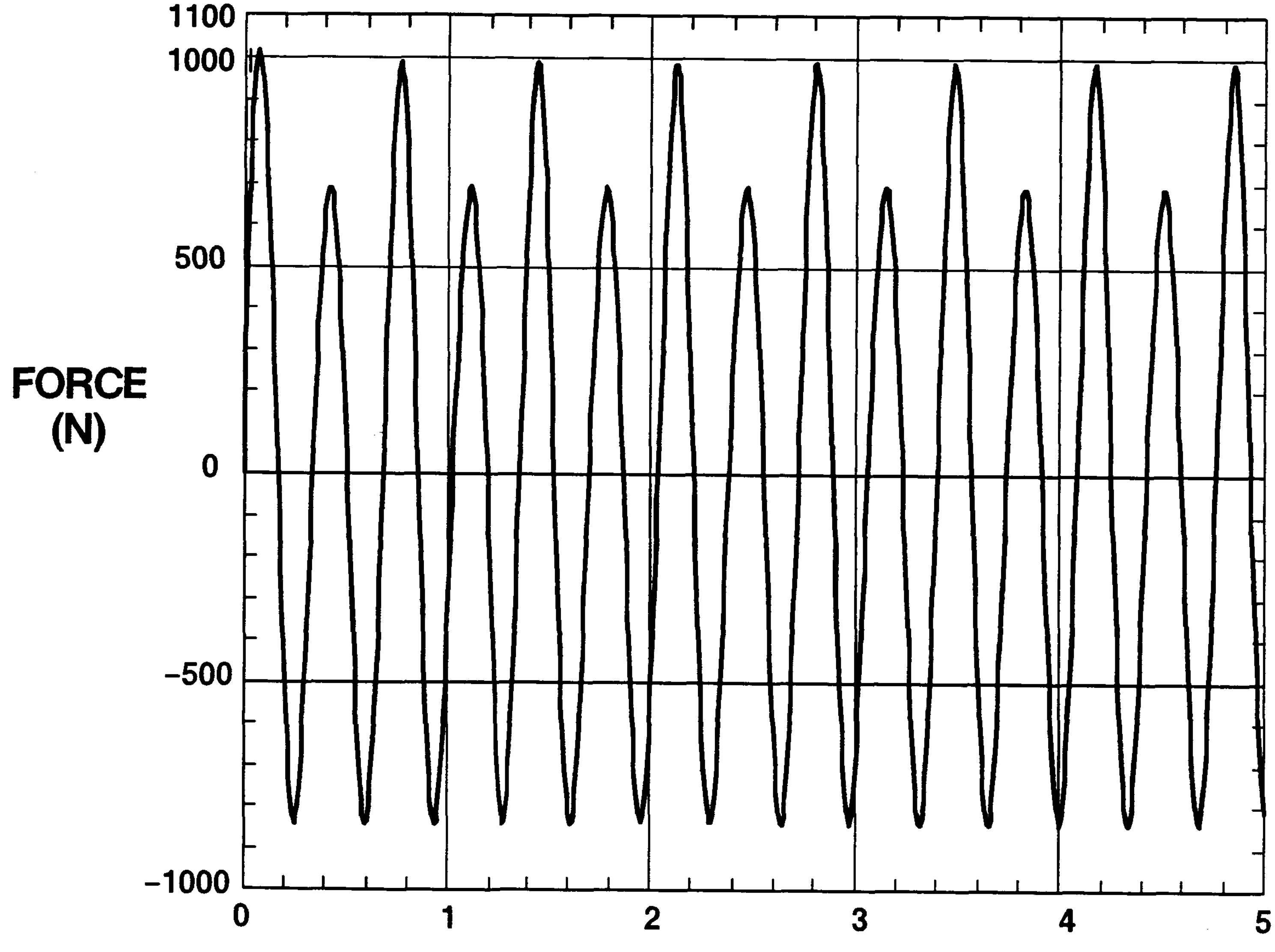

YAW AND PITCH
ANGLES VS TRUE ANOMALY
ORBITER / CDSF ATTITUDE STABILITY
YAW & PITCH ANGLES (DEG)
30
20
10
0
-10
-20
-30
0
1.0
2.0
3.0
4.0
5.0
ORBIT
YAW
PITCH

DYNAMIC DISTURBANCES TO THE MICROGRAVITY ENVIRONMENT

In addition to the steady-state environmental disturbances (gravity gradient, drag, etc.) which act upon the CDSF, certain dynamic disturbances will affect the microgravity environment, especially those due to the presence of crew members during man-tended operations.

Shown here is an example of the forcing function that results from a 190 pound crew person exercising on a treadmill. This data was provided by Dr. C.E. Larsen of the Johnson Space Center based on experimentally measured footfall forces resulting from investigations by astronaut Dr. W.E. Thornton. It is representative of the exercise patterns that is being studied for long duration human space missions such as Space Station Freedom and Extended Duration Orbiter. This exercise represents a 3 mile per hour walk and a 6 mile per hour jog. As shown the amplitude of this disturbance is 1000 Newtons (225 lbs) at a frequency of 2.9 Hz.

TREADMILL FORCING FUNCTION
(190 lb CREWMAN @ 6 mph JOG)



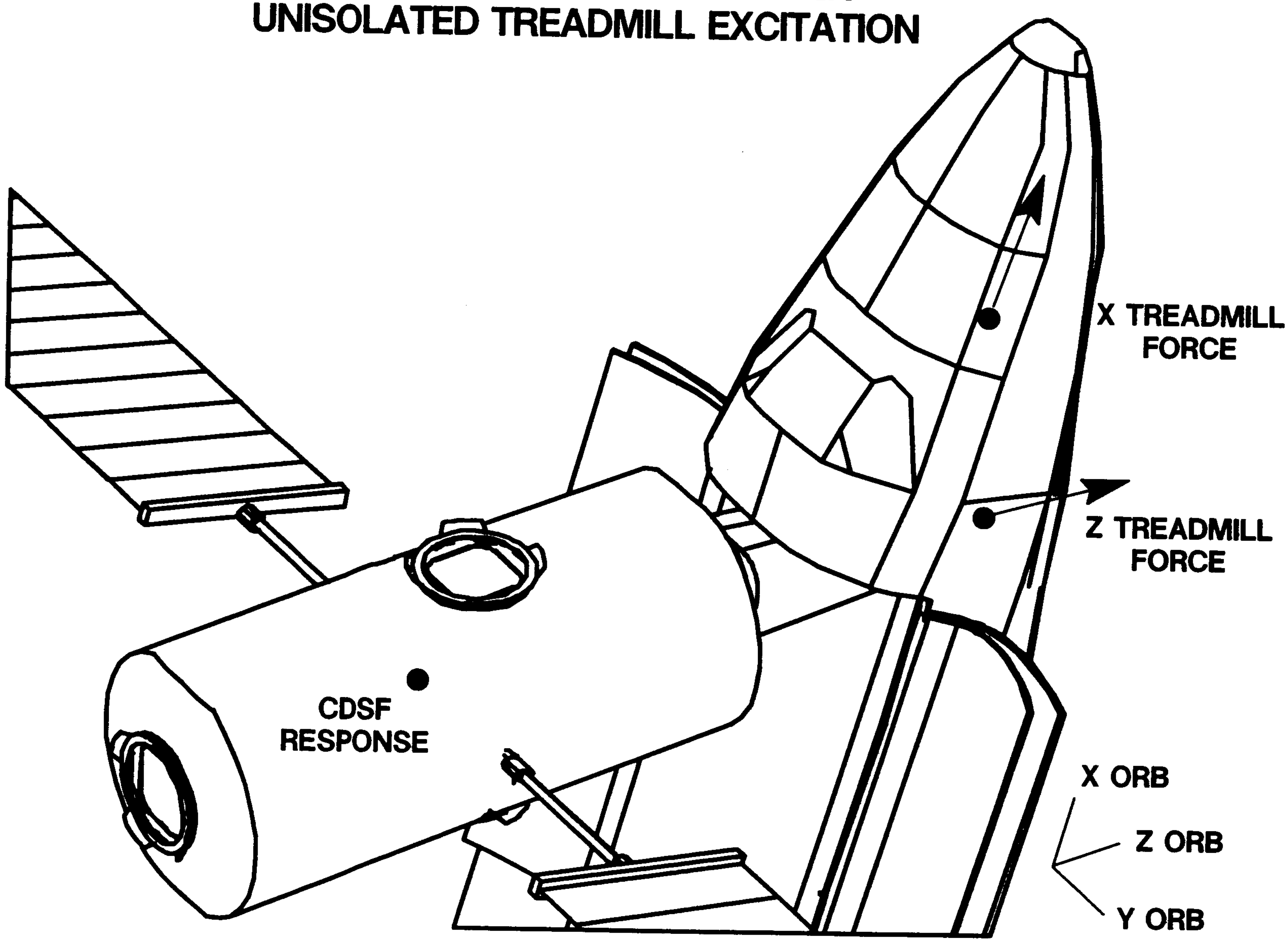
treadmil.int

TREADMILL LOCATIONS

Two potential treadmill locations aboard the CDSF/STS configuration are illustrated. The treadmill at the location closest to the nose of the Orbiter is oriented such that the treadmill generated force is aligned along the X Orbiter axis, as shown on the figure. The treadmill at the location further aft is oriented such that the treadmill generated force is along the Z Orbiter axis direction.

On subsequent charts, the CDSF rigid body response to these forcing functions is calculates at the response point indicated which was chosen to be in the center of the experiment laboratory section.

CDSF RESPONSE TO ORBITER UNISOLATED TREADMILL EXCITATION

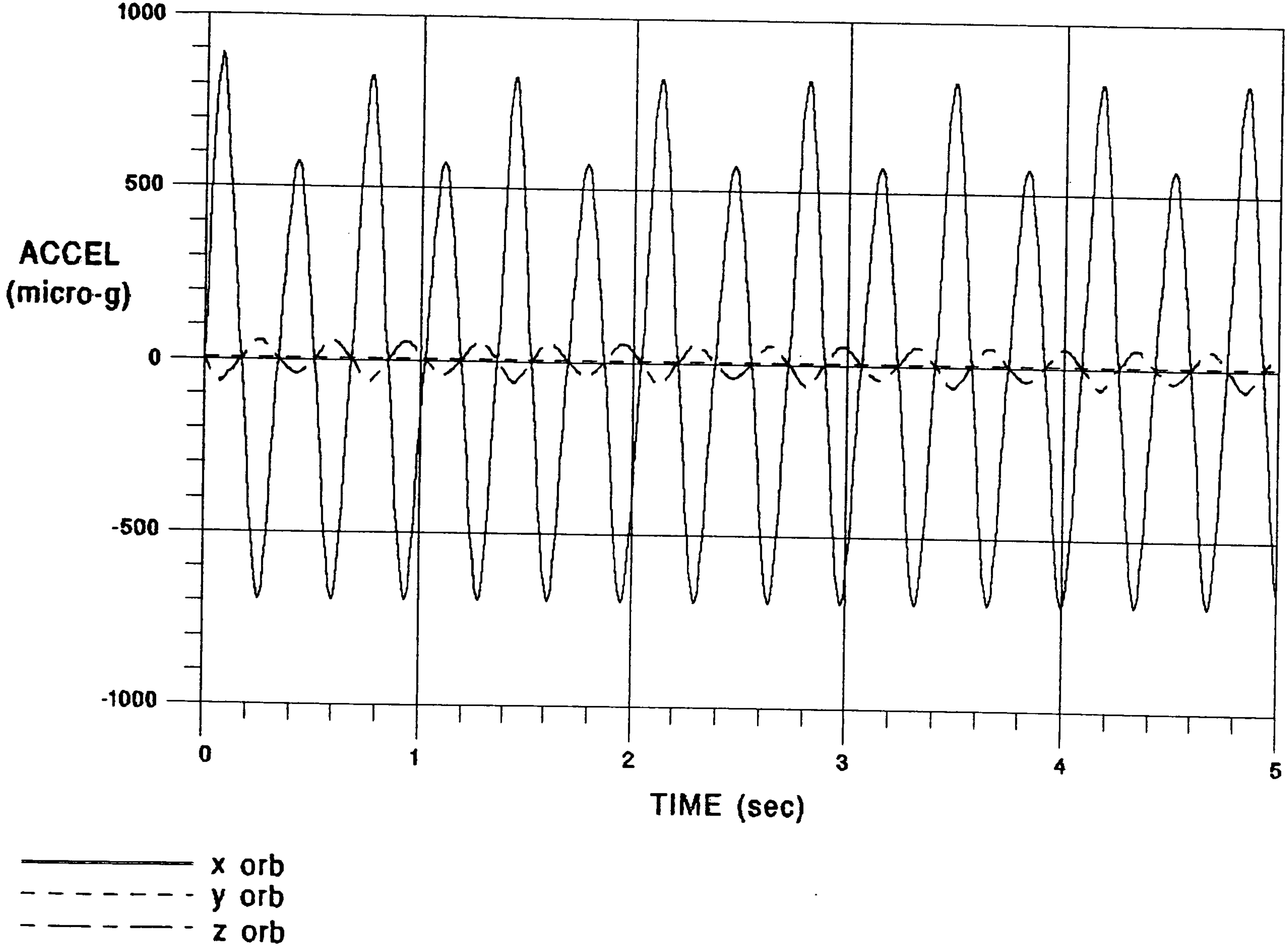


brenth.int

CDSF RESPONSE TO X ORBITER TREADMILL FORCE

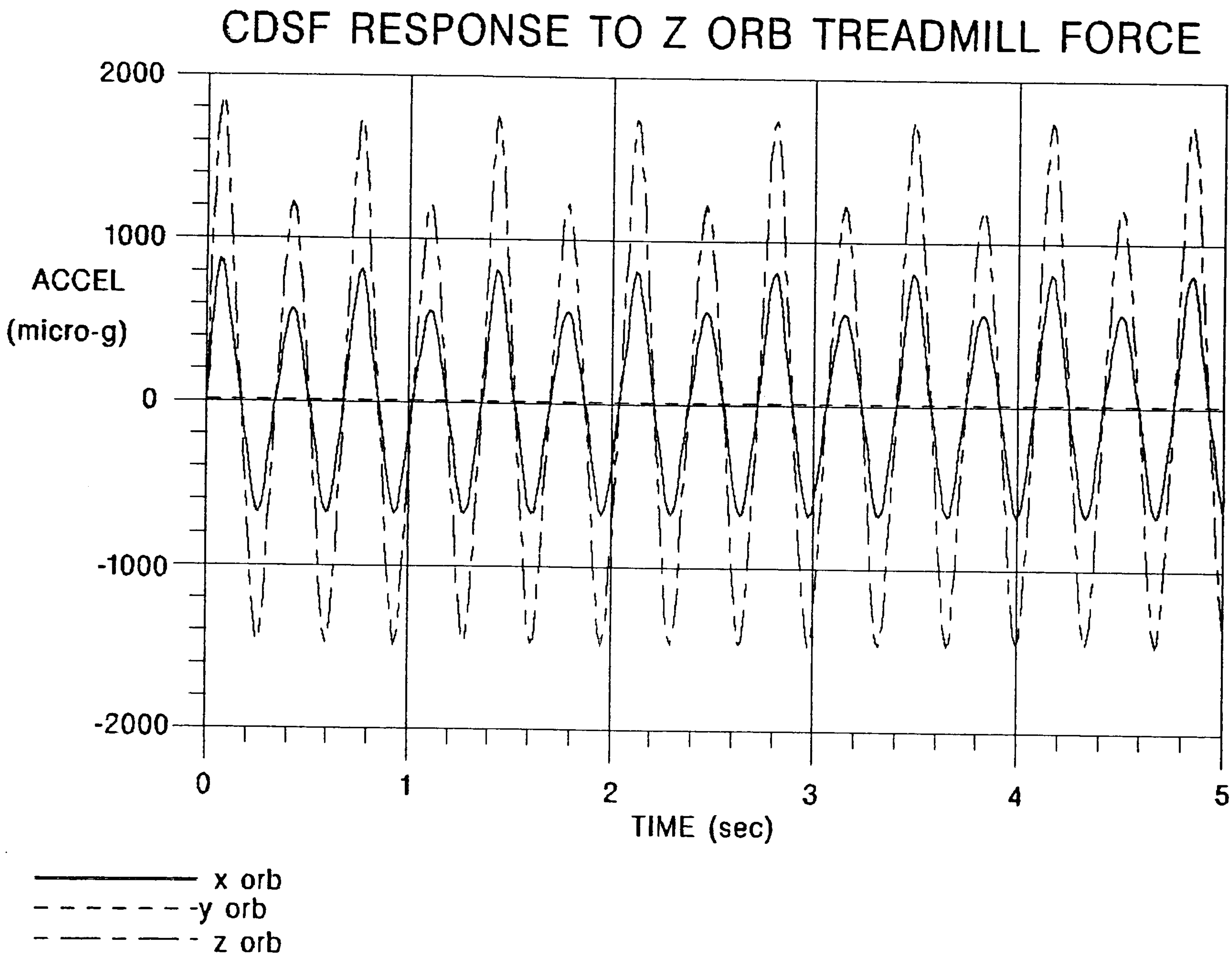
The un-isolated rigid body response in the CDSF laboratory section due to the X directional treadmill forcing function described previously is shown. As can be seen, the primary component of the sensed acceleration in the CDSF is along X, which is in a direction along the diameter width of the laboratory section. The response frequency is the same as the input forcing function frequency and the amplitude is nearly 1000 micro-G.

CDSF RESPONSE TO X ORB TREADMILL FORCE



CDSF RESPONSE TO Z ORBITER TREADMILL FORCE

The un–isolated rigid body response of the CDSF due to the Z directional treadmill forcing function is shown here. The primary component of the sensed acceleration in the CDSF laboratory section is along the Z axis, which is along the length of the CDSF. It results not only from the direct translational acceleration due to the forcing function, but also due to the resulting oscillatory angular acceleration which the CDSF/STS experiences. The combined sum yields an amplitude of nearly 2000 micro–G. A sizable X component of peak sensed acceleration (-800 micro–G) resulting from the rotational motion due to angular velocity can also be observed.


CDSF RESPONSE TO Z ORB TREADMILL FORCE
2000
1000
0
-1000
-2000
ACCEL
(micro-g)
0
1
2
3
4
5
TIME (sec)
x orb
y orb
z orb

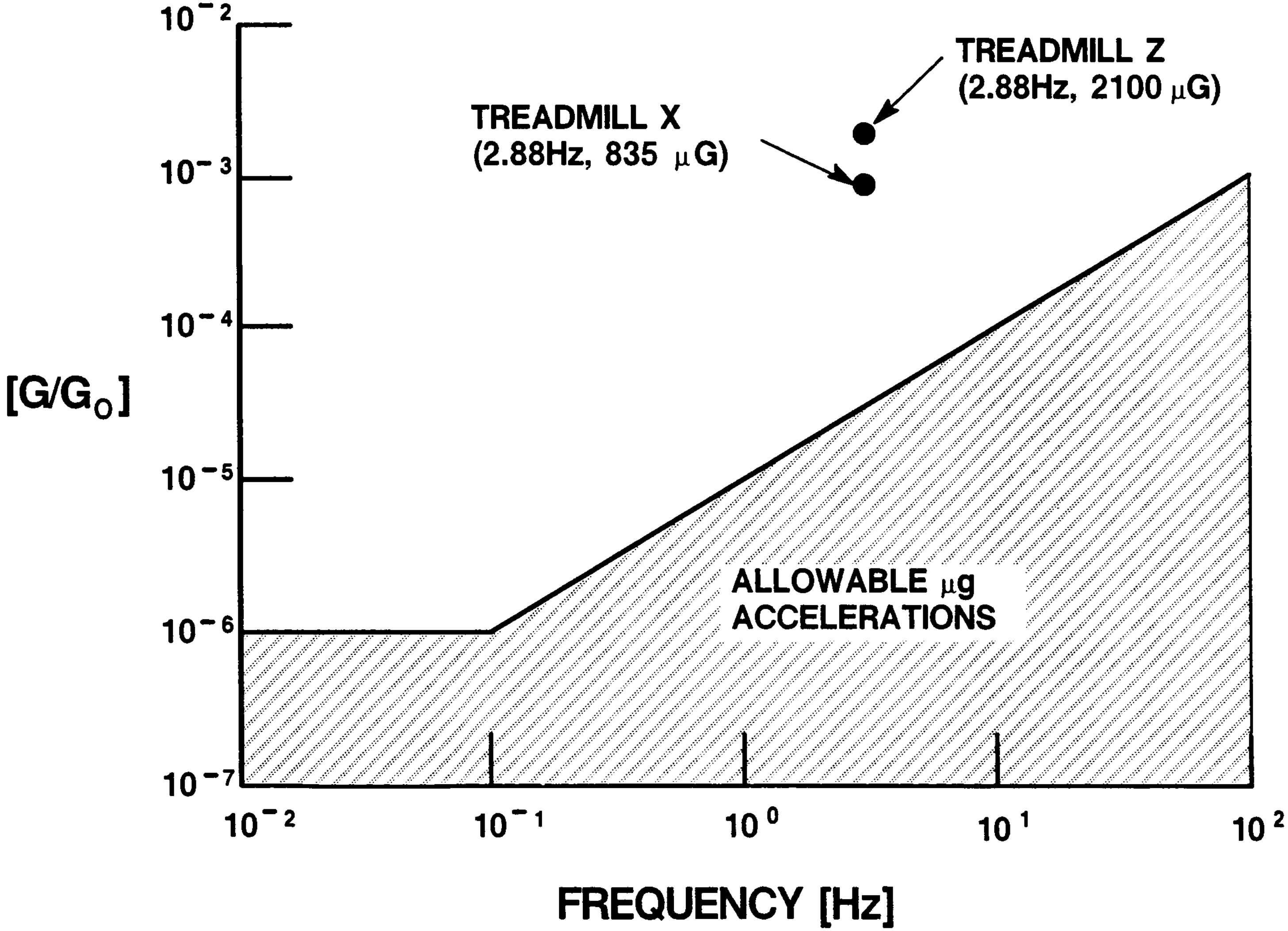
TREADMILL RIGID BODY ACCELERATION RESULTS VS MICROGRAVITY REQUIREMENTS

An illustration of the magnitude of the crew exercise induced acceleration disturbance is shown with respect to the NASA defined microgravity experiment requirements as a function of magnitude versus frequency. The un-isolated treadmill disturbance exceeds the microgravity requirements by nearly two orders of magnitude. This result emphasizes the need to isolate crew disturbances from the CDSF micro-G experiments for CDSF/STS mission man-tended missions.

Since the Z treadmill induced acceleration of magnitude 2100 micro-G at the CDSF exceeds the 30 micro-G requirement, a 99% efficient isolation mechanism would be required to meet the stated requirements.

Another effect to be considered in addition to crew exercise is crew motion disturbance in the CDSF laboratory section itself. A typical crew push-off maneuver creates a 25 lb disturbance force, which yields an un-isolated 100 micro-G step impulse disturbance.

TREADMILL RIGID BODY ACCELERATION RESULTS vs. MICROGRAVITY REQUIREMENTS



TREAD

MICROGRAVITY DYNAMIC DISTURBANCES

The un-isolated treadmill forcing function acting in the Orbiter x direction induces a peak acceleration of 835 micro-g in the CDSF. The un-isolated treadmill forcing function acting in the Orbiter z direction induces a peak acceleration of 2100 micro-g in the CDSF. If un-isolated, both disturbances exceed the microgravity requirement at 2.9 Hz of 30 micro-g. A 99 percent efficient isolator mechanism would be required to meet microgravity requirements during crew exercise.

A typical crew push-off forcing function of 25 lb to move a 150 lb crew person 2.7 ft/sec results in a 100 micro-g impulse. The induced acceleration impulse is reduced to 10 micro-g if crew push-off is limited to 2.5 lb.

MICROGRAVITY DYNAMIC DISTURBANCES

- PEAK UNISOLATED X–TREADMILL ACCELERATION EXPERIENCED IN CDSF: 835 μg
  PEAK UNISOLATED Z–TREADMILL ACCELERATION EXPERIENCED IN CDSF: 2100 μg

- RIGID BODY CDSF RESPONSE TO EITHER UNISOLATED TREADMILL EXCITATION FUNCTION EXCEEDS THE MICROGRAVITY REQUIREMENTS (~ 30 μg @ 2.88 Hz)

  NOTE: FLEXIBLE BODY COUPLING WITH SOLAR ARRAYS NOT STUDIED

- A 99% EFFICIENT TREADMILL ISOLATOR MECHANISM WOULD BE REQUIRED TO MEET MICROGRAVITY REQUIREMENTS WHILE EXERCISING

- CREW SOARING
  - TYPICAL PUSH–OFF OF 25 LB RESULT IN A 100 μg STEP IMPULSE (MOVES 150 LB CREWMAN 2.7 FT/SEC)
  - 2.5 LB PUSH–OFF YIELDS 10 μg ACCELERATION (CREWMAN MOVES 16 FT/MIN)

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5.2.1.3. FLIGHT MODE THERMAL ASSESSMENT

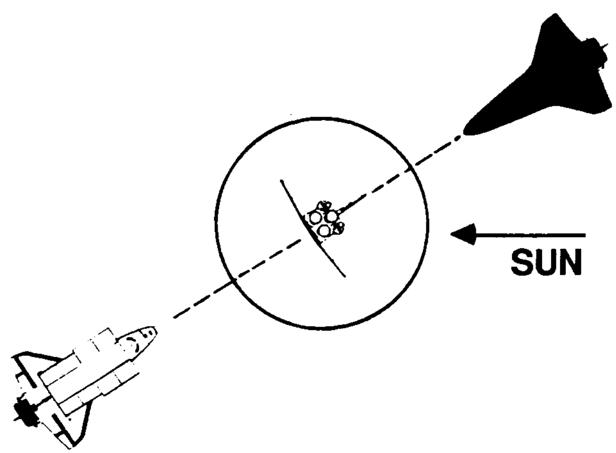
STS FLIGHT ORIENTATION THERMAL ANALYSIS

In order to provide microgravity experiments on board the CDSF with longer experiment run times than currently achieved with STS missions, the Orbiter with the CDSF attached will be oriented in a nose down Local Vertical Local Horizontal (LVLH) flight attitude. This flight orientation is gravity gradient stable and thus minimizes reaction control system vernier thrust activity. Since the desired flight orientation is not referenced in NSTS 07700, Vol. 14, Appendix 2 System Description and Design Data - Thermal, a thermal analysis was made to assess temperature profiles created in the Orbiter cargo bay and on the CDSF. To account for all possible seasonal variations, a thermal analysis was performed for both low (0 deg) and high (52 deg) relative sun/CDSF angles, beta.

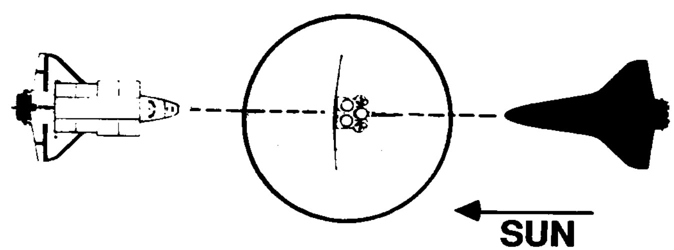
STS FLIGHT ORIENTATION THERMAL ANALYSIS

- STS NOSE TO NADIR LOCAL VERTICAL LOCAL HORIZONTAL IS PREFERRED CDSF CREW TENDED OPERATION FLIGHT MODE
  - GRAVITY GRADIENT STABLIZED
  - MINIMIZES RCS VERNIER ACTIVITY FOR MAXIMUM TIME PERIODS OF LOW MICRO G CONDITIONS
- DESIRED FLIGHT MODE NOT REFERENCED IN NSTS 07700, VOLUME 14, APPENDIX 2 SYSTEM DESCRIPTION AND DESIGN DATA - THERMAL
  - HIGH BETA AND LOW BETA THERMAL ANALYSIS PERFORMED TO ASSESS HOT/COLD CONDITIONS

HIGH BETA = 55°



LOW BETA = 0°



MN/C4

STS / CDSF CREW TENDED FLIGHT MODE THERMAL ANALYSIS RESULTS

Thermal analysis results showed that maximum average temperatures were observed just prior to the configuration entering the Earth's shadow. The coldest average temperature occurred just prior to leaving that shadow. At no time did the Orbiter payload bay exceed 100 deg C or go below −120 deg C. The CDSF stayed in the range of −125 deg C to 63 deg C. As may be seen from the thermal analysis summary shown, the addition of the CDSF had a negligible effect on the minimum cargo bay temperature, with the maximum cargo bay temperature decreasing by 10 deg C in the 0 degree, sun straight on case (caused by increased shadowing), and the maximum cargo bay temperature increasing by 25 deg C in the 52 degree case (caused by increased cargo bay internal reflections). In all events, the predicted temperatures were well within the limits expressed in NSTS 07700, Vol. 14, Appendix 2, Figure 2-1: −156 deg C to 163 deg C.

STS / CDSF CREW TENDED FLIGHT MODE THERMAL ANALYSIS RESULTS

	$\beta = 0°$		$\beta = 52°$	
ORBIT:				
Altitude, nautical miles	174.00		174.00	
Period, minutes	90.00		90.00	
Eclipse start time, minutes	26.97		29.97	
Eclipse end time, minutes	63.03		60.03	
Duration in sunlight, minutes (% of period)	53.94 (59.93)		59.94 (66.60)	
Duration in eclipse, minutes (% of period)	36.06 (40.07)		30.06 (33.40)	
CDSF:	**Orbiter Alone**	**Mated w/CDSF**	**Orbiter Alone**	**Mated w/CDSF**
Minimum Temp °C (@ orbit time, min)	-	-125.41 (63)	-	-125.06 (54)
Maximum Temp °C (@ orbit time, min)	-	62.86 (18)	-	48.03 (27)
ORBITER PAYLOAD BAY:				
Minimum Temp °C (@ orbit time, min)	-118.37 (54)	-118.99 (45)	-116.95 (54)	-115.35 (45)
Maximum Temp °C (@ orbit time, min)	99.95 (9)	89.22 (18)	72.31 (27)	97.49 (18)
NSTS 07700 VOL XIV Appendix 2:				
Open door on-orbit payload bay temperature range (Figure 2-1)				
Minimum Temp °C	-156			
Maximum Temp °C	163			

THERMAL ANALYSIS TEMPERATURE PROFILES

The orbiting configuration was modeled and simulated in low Earth (174 nautical miles) 90 minute orbits, until a cyclic steady state was reached (that is, the temperature at any point was the same as it was when at the same part of its last orbit).

The solar heat flux used for this analysis was 1335 W/m**2; Earth-reflected albedo flux was 244 W/m**2.

The models of the Orbiter and CDSF were made of materials with two different radiative properties: 1) white (Orbiter tiles and the CDSF body) with an absorptivity of 0.32 and an emissivity of 0.80, and 2) black (Orbiter underside) with an absorptivity of 0.80 and an emissivity of 0.85. The outward-facing, top half surface of the CDSF was assumed to be entirely covered with body-mounted, single-phase fluid radiators at 20 deg C.

The temperature profile of the Orbiter/CDSF just prior to eclipse is illustrated for both low (0 deg) and high (52 deg) solar beta geometry.

THERMAL ANALYSIS TEMPERATURE PROFILES

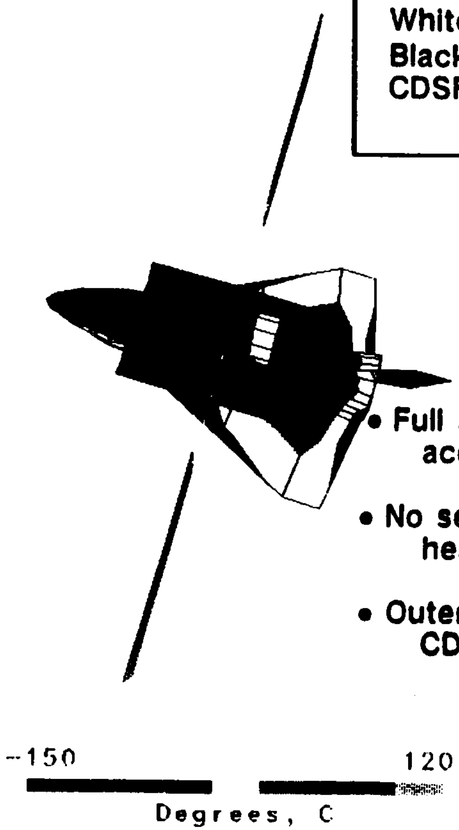
MODEL ASSUMPTIONS

Q solar = 1353 W/m ^{2} (1353 $\pm$ 46. user avg.)
Q albedo = 244 W/m ^{2} (237 $\pm$ 7, use max.)
Min β = 0
Max β = sun inclination ($\pm$ 23.6°)
= Latitude of KFC (28.4°) = 52°

Radiative material properties:

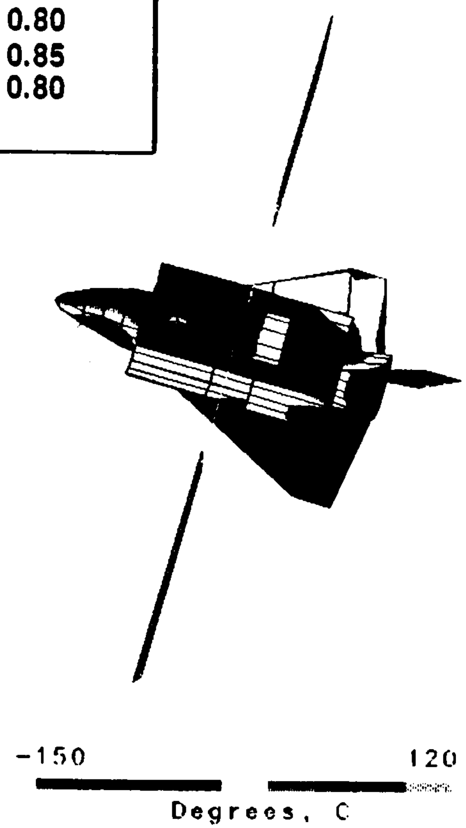
	Absorptivity	Emissivity
White orbiter tiles	0.32	0.80
Black orbiter tiles	0.80	0.85
CDSF	0.32	0.80

β = 0°



- Full Sun-Earth-Orbiter Shadowing accounted for
- No self-specular radiation or internal heat rejection visibility
- Outer (top 1/2) cylindrical) surface of CDSF radiators at constant T=20° C

β = 52°



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5.2.1.4. EXTENDED DURATION ORBITER MISSION

Extended Duration Orbiter (EDO) Study Objectives

An EDO flight is capable of supporting up to a 25 day mission. The Orbiter is outfitted with a 2948 Kg Power Augmentation pallet. The objective of this study was to determine whether the extended mission had any significant impact on the microgravity results obtained for a nominal Orbiter mission without EDO kits.

Thus, a similar set of analyses were performed, including an assessment of sun-tracking vs feathered solar array orientation, steady state micro-g environment determination, and sources of dynamic microgravity disturbances.

The key differences between the EDO Orbiter and the nominal Orbiter fall into three categories : 1) the extended length of the mission, which implies longer experiment operational periods, and impacts of crew exercise schedules, 2) the impact of the cryo kit which augments the amount of power available to support mated experimentation, 3) the additional Orbiter mass which impacts deployment and/or rendezvous altitude capacity. The impact of an expanded treadmill exercise program will increase the amount of time that the CDSF is exposed to crew induced dynamic micro-g disturbances, the results of which were discussed in Section 5.2.1.2.

The EDO power augmentation pallet has a mass of about 2948 kg (including equipment for attaching it to the cargo bay), has a diameter of 14.5 feet and uses about 7 feet in the rear of the orbiter cargo bay. This impacts available orbiter lift and volume in such a manner that the EDO pallet and the CDSF cannot be lifted on the same flight. However, for flights other than the initial deployment flight, the EDO pallet can be used to extend the stay time in orbit for additional experimentation on the CDSF.

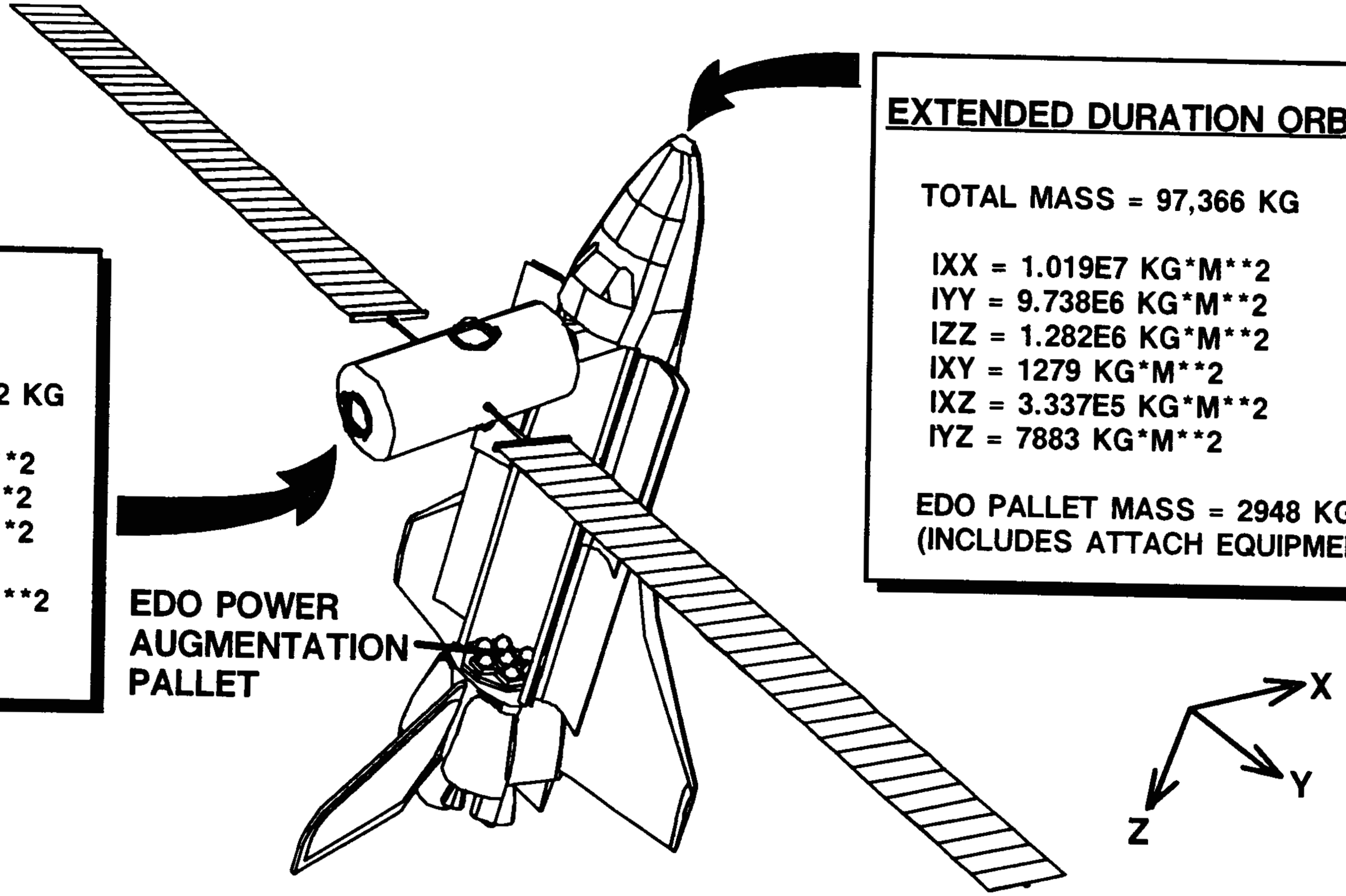
The mated CDSF/EDO configuration mass and inertia properties are shown. It will be shown that this mated configuration will also yield a passively stable gravity gradient flight mode.

CDSF/EDO ORBITER MASS PROPERTIES

CDSF

TOTAL MASS = 14,652 KG

IXX = 2.843E5 KG*M**2
IYY = 2.185E5 KG*M**2
IZZ = 4.300E5 KG*M**2
IXY = 0 KG*M**2
IXZ = -4.191E4 KG*M**2
IYZ = 0 KG*M**2



EXTENDED DURATION ORBITER

TOTAL MASS = 97,366 KG

IXX = 1.019E7 KG*M**2
IYY = 9.738E6 KG*M**2
IZZ = 1.282E6 KG*M**2
IXY = 1279 KG*M**2
IXZ = 3.337E5 KG*M**2
IYZ = 7883 KG*M**2

EDO PALLET MASS = 2948 KG
(INCLUDES ATTACH EQUIPMENT)

CDSF/EDO CONFIGURATION PROPERTIES

TOTAL MASS = 111,988 KG

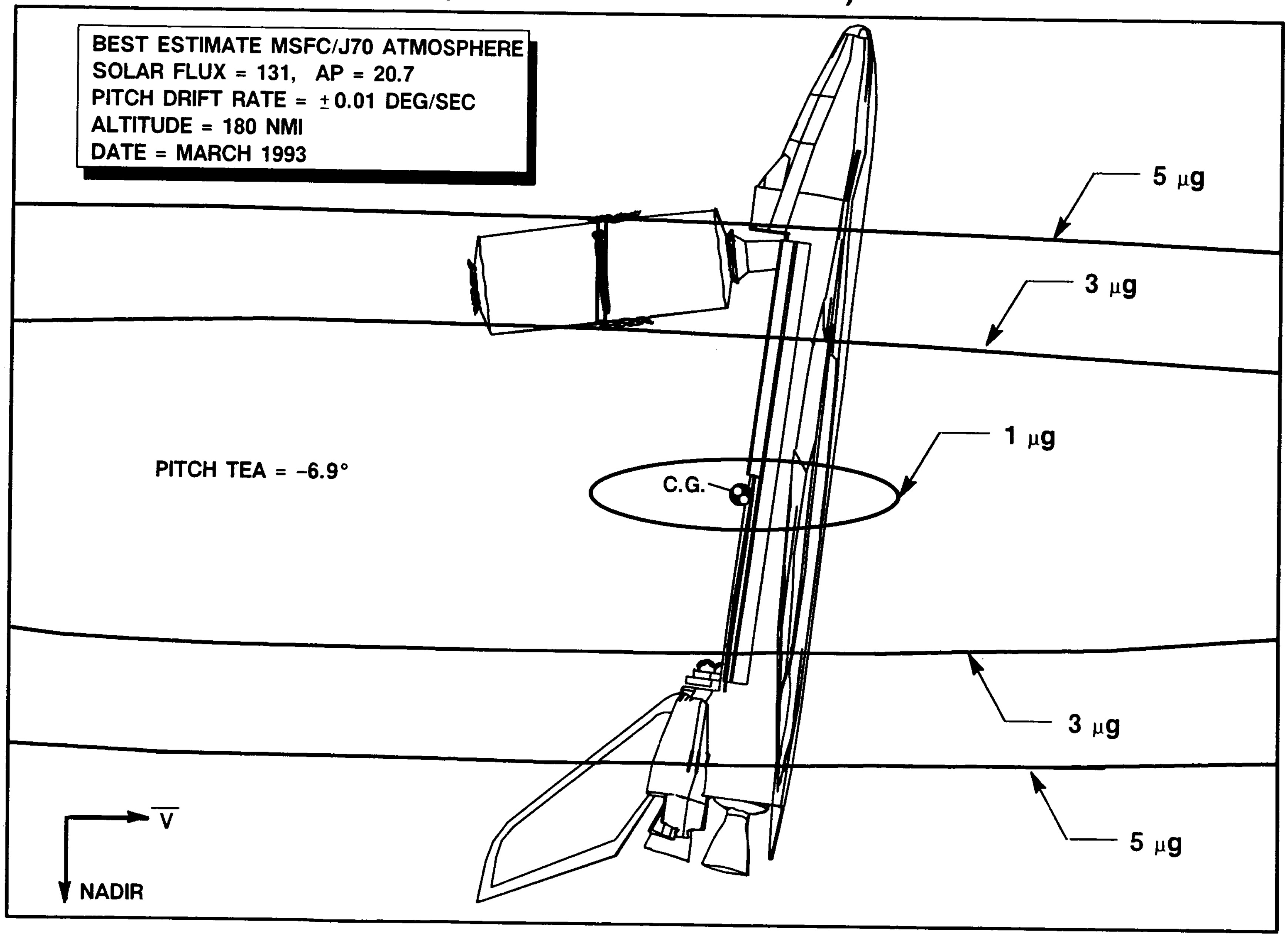
IXX = 1.158E7 KG*M**2
IXY = 978 KG*M**2
IYY = 1.203E7 KG*M**2
IXZ = 1.327E6 KG*M**2
IZZ = 2.680E6 KG*M**2
IYZ = 7560 KG*M**2

CDSF/ORBITER STEADY STATE MICROGRAVITY PROFILE (SUN-TRACKING ARRAYS)

The steady-state micro-g environment for a CDSF/EDO configuration is shown. The torque equilibrium attitude (TEA) was found to be -6.9 degrees in pitch (i.e., forward into the direction of flight). At this attitude, the configuration was passively stable, that is, no attitude control authority was required to maintain attitude. The flight date assumed for this study was March 1993. The initial altitude was 180 Nm. The August '88 MSFC best estimate atmosphere was assumed; i.e., a solar flux value of 131, and a geomagnetic index of 20.7.

In this CDSF/EDO configuration depicted, the entire CDSF experiences between a 3 to 5 micro-g acceleration level due to displacement from the center of gravity. However, the $\pm$ 5 degree acceleration vector deviation requirement is maintained.

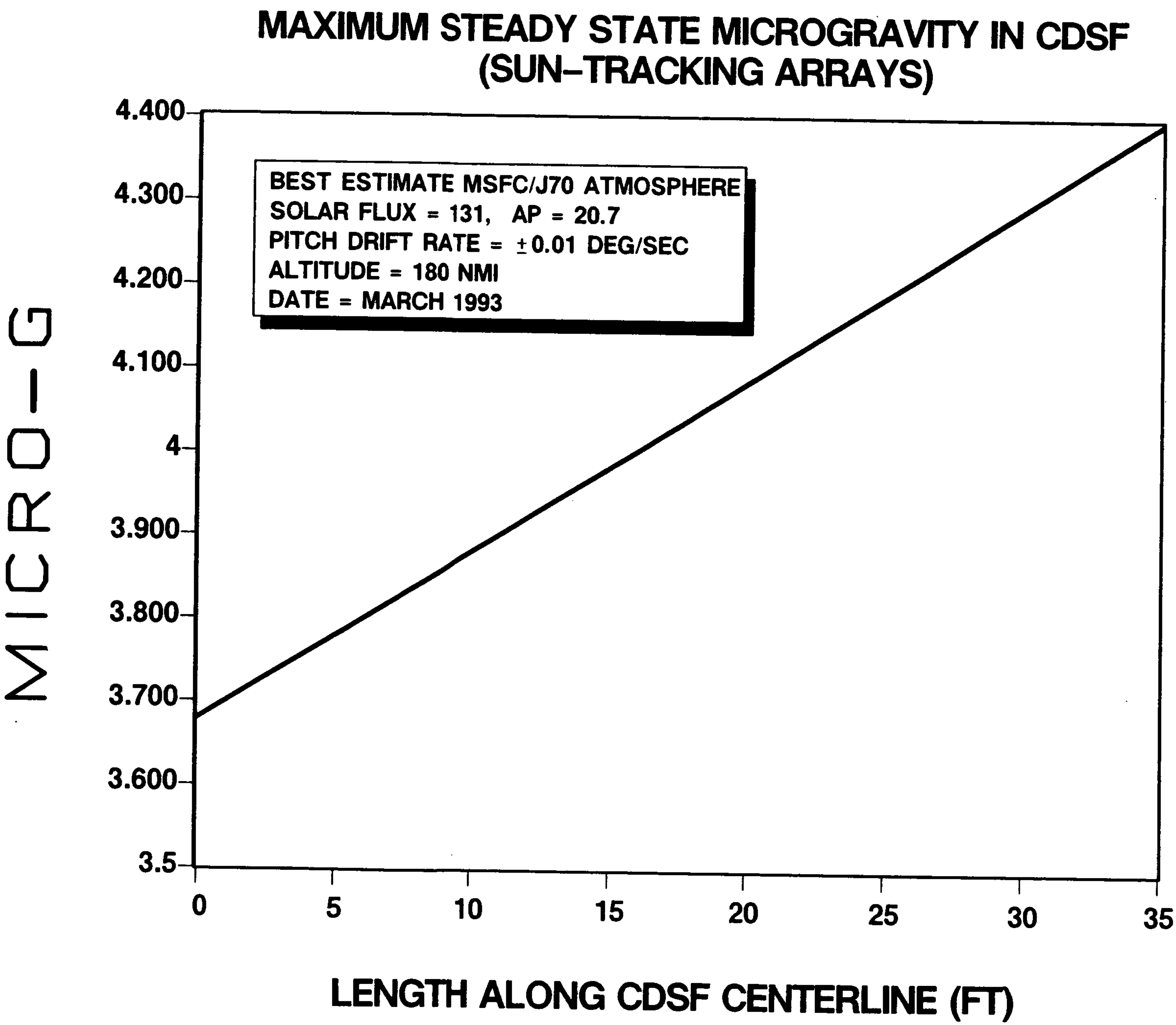
CDSF/ORBITER STEADY STATE MICROGRAVITY PROFILE (SUN–TRACKING ARRAYS)



suntrack

MAXIMUM STEADY STATE MICROGRAVITY IN CDSF (SUN-TRACKING ARRAYS)

The peak steady-state micro-G along the centerline of the CDSF is seen to vary from 3.7 micro-G to 4.4 micro-G. The primary acceleration contribution was due to gravity gradient, because of the relatively large CDSF/EDO composite c.g. offset of about 11 meters along the Z axis. A secondary contribution was the pitch drift rate peak value of + 0.01 deg/sec which contributed to closing off the ends of the micro-G ellipses depicted. Contributing only about 10% to the acceleration level was the aerodynamic induced drag, which varied from 0.28 to 0.73 micro-G. Thus, even the so-called "steady-state" micro-G actually varies by a small amount over an orbit due to articulating solar arrays and a diurnal bulge in the atmospheric density profile. The flight date assumed for this study was March 1993. The initial altitude was 180 Nm.

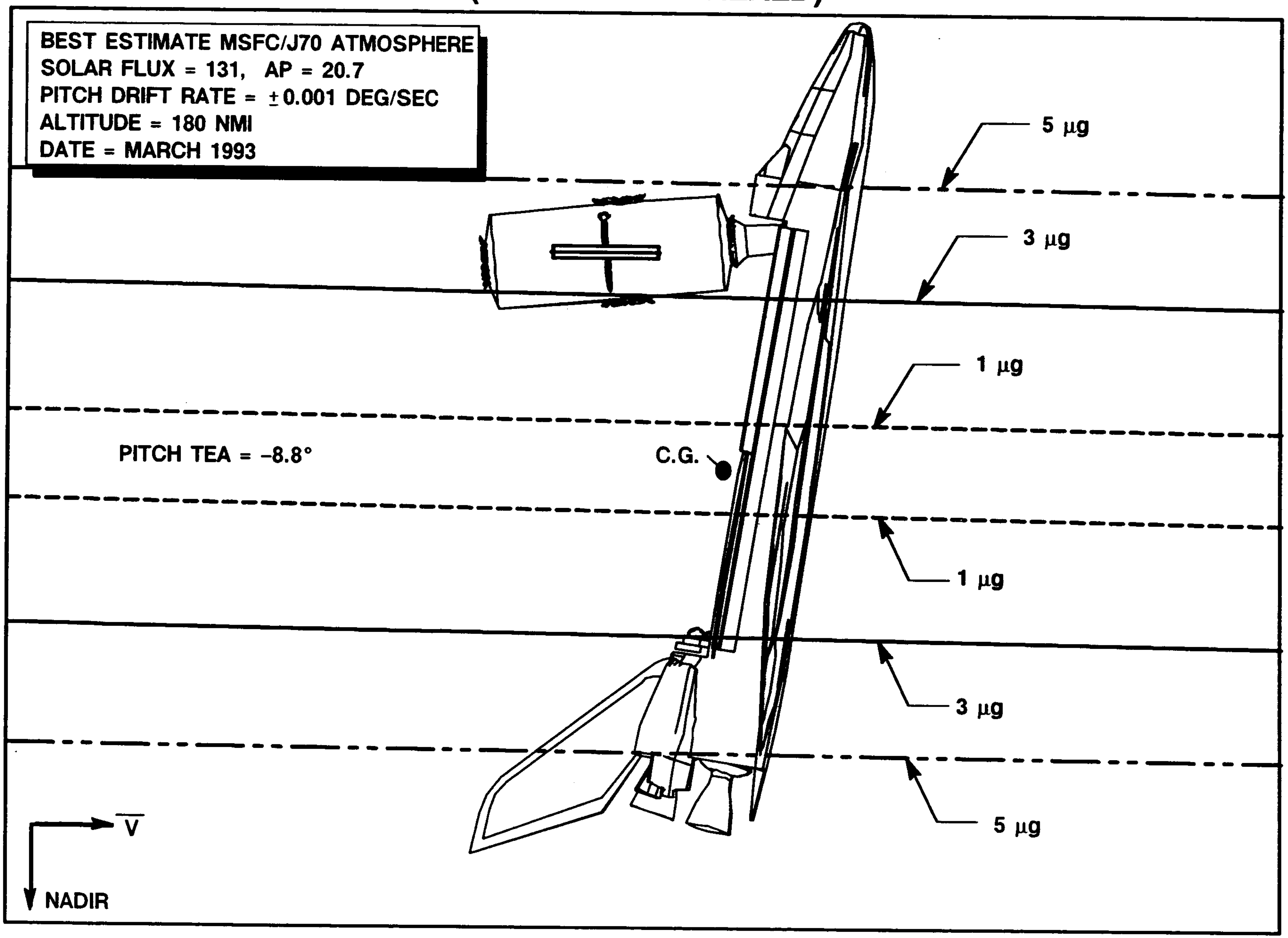

MAXIMUM STEADY STATE MICROGRAVITY IN CDSF
(SUN–TRACKING ARRAYS)
BEST ESTIMATE MSFC/J70 ATMOSPHERE
SOLAR FLUX = 131, AP = 20.7
PITCH DRIFT RATE = ±0.01 DEG/SEC
ALTITUDE = 180 NMI
DATE = MARCH 1993
MICRO–G
4.400
4.300
4.200
4.100
4
3.900
3.800
3.700
3.600
3.5
0
5
10
15
20
25
30
35
LENGTH ALONG CDSF CENTERLINE (FT)

MGCHART

CDSF/ORBITER STEADY STATE MICROGRAVITY PROFILE (ARRAYS FEATHERED)

A steady-state micro-G environment is shown for a CDSF/EDO configuration with solar arrays oriented in a feathered mode. The torque equilibrium attitude (TEA) was found to be -8.8 degrees in pitch (forward). At this attitude, the configuration was also passively stable, that is, no attitude control authority was required to maintain attitude. Flight dates, altitude, and atmospheric model data were the same as for the sun-tracking solar arrays simulation.

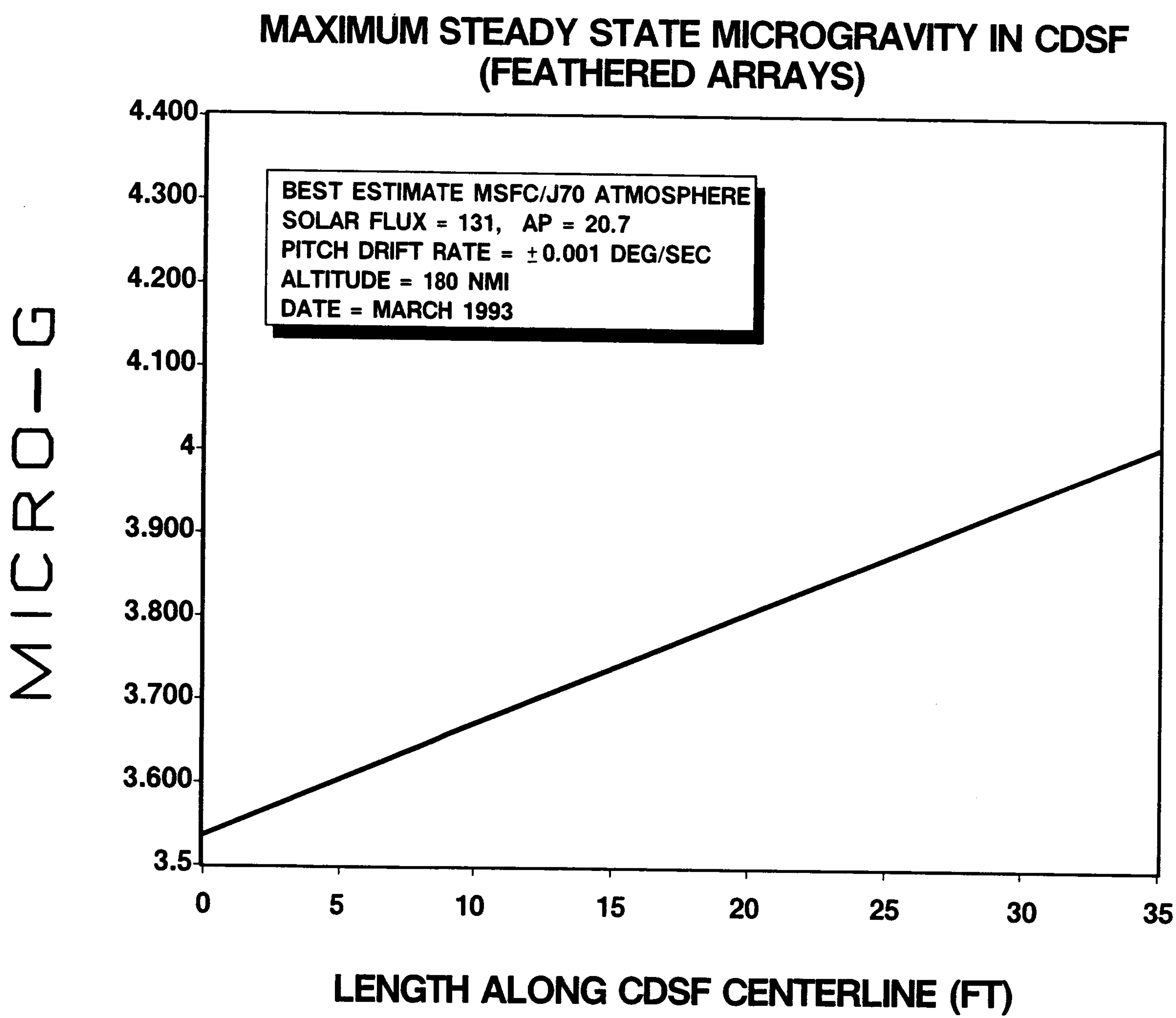
CDSF/ORBITER STEADY STATE MICROGRAVITY PROFILE (ARRAYS FEATHERED)



FEATHER2

MAXIMUM STEADY STATE MICROGRAVITY IN CDSF (FEATHERED ARRAYS)

The peak steady-state acceleration along the centerline of the CDSF is seen to vary from 3.5 micro-G to 4.0 micro-G. As was the case for sun-tracking mode, the primary contributor was gravity gradient. Rotational induced accelerations and aerodynamic drag were quite small. Drag varied over each orbit from 0.27 micro-G to 0.54 micro-G (due to the diurnal density bulge in the atmosphere).


MAXIMUM STEADY STATE MICROGRAVITY IN CDSF
(FEATHERED ARRAYS)
BEST ESTIMATE MSFC/J70 ATMOSPHERE
SOLAR FLUX = 131, AP = 20.7
PITCH DRIFT RATE = ±0.001 DEG/SEC
ALTITUDE = 180 NMI
DATE = MARCH 1993
MICRO-G
4.400
4.300
4.200
4.100
4
3.900
3.800
3.700
3.600
3.5
0
5
10
15
20
25
30
35
LENGTH ALONG CDSF CENTERLINE (FT)

MGCHARTFEA

CDSF/EDO FLIGHT MODE CHARACTERISTICS

A summary of the flight mode characteristics for the 2 CDSF/EDO flight scenarios simulated for sun-tracking solar arrays and feathered solar arrays is shown. Note that : 1) both have low, nearly local vertical (tail-down) TEA attitudes, 2) both are passively stable, although the sun-tracking mode results in somewhat larger oscillations induced by aerodynamics resulting from array articulation as shown in the ''passive attitude stability" columns, and 3) both have orbit lifetimes in excess of the 25 day maximum mission. The feathered mode has a 67 day mission orbit lifetime (assuming a +2 sigma atmosphere model) while the sun-tracking mode has a 50 day lifetime, starting from the same 180 Nm altitude. This results directly from the minimal area / high ballistic coefficient of 96 Kg/met**2 for the feathered configuration vs 72 Kg for the sun-tracking array configuration.

CDSF/EDO FLIGHT MODE CHARACTERISTICS

	PRINCIPLE TO BODY AXIS EULER ANGLES (DEG)	TORQUE EQUILIBRIUM ATTITUDE (DEG)	PASSIVE ATTITUDE STABILITY		BALLISTIC COEFFICIENT (KG/M^2)	ORBIT LIFETIME FROM 180 NMI (DAYS)
			ANGLE (DEG)	RATE (DEG/SEC)		
SUN–TRACKING						
YAW (Z)	0.0	0.0				
PITCH (Y)	–8.3	–6.9	± 4	± 0.01	72	50
ROLL (X)	0.0	0.0				
FEATHERED						
YAW (Z)	0.0	0.0				
PITCH (Y)	–8.3	–8.8	± 1	± 0.001	96	67
ROLL (X)	0.0	0.0				

MICROGRAVITY STEADY STATE DISTURBANCES

The steady-state microgravity results are summarized. The 200 micro-G acceleration which could result from the firing of the Orbiter VRCS necessitates the consideration of passive gravity gradient flight mode stability if viable CDSF/EDO missions are to be considered.

MICROGRAVITY STEADY STATE DISTURBANCES

- RESULTS FROM
  - GRAVITY GRADIENT
  - DRAG
  - ROTATIONAL MOTION

- PRIMARY SOURCE OF STEADY STATE MICRO–G FOR MATED CDSF/EDO IS GRAVITY GRADIENT DUE TO DISPLACEMENT OF CDSF FROM COMPOSITE CENTER OF MASS AND TEA ATTITUDE

- STEADY STATE MICROGRAVITY IN CDSF ~ 3.5 – 4.5 μg

- CONTRIBUTION DUE TO DRAG : 0.7 μg (SUN–TRACKING)
(@ 180 NMI, BEST ESTIMATE ATMOSPHERE) 0.5 μg (FEATHERED)

- THE ORBITER VERNIER JETS USED FOR ATTITUDE MAINTENANCE ARE UNCOUPLED, ie., RESULT IN NET TRANSLATION FORCES OF UP TO 50 LB DEPENDING ON THE ATTITUDE ERROR WHICH YIELDS A 200 μg TRANSLATIONAL ACCELERATION.

EDO Summary

An Extended Duration Orbiter mission with a representative Commercially Developed Space facility was analyzed in this study. It was determined that the configuration had a stable, tail-down nearly LVLH torque equilibrium attitude. For the sun-tracking CDSF solar array configuration, pitch oscillations of plus or minus 5 degrees and plus or minus 0.01 deg/sec can be maintained in a passively stable flight attitude (i.e., without any attitude control authority). For the feathered solar array configuration, pitch oscillation magnitudes were reduced to 1 degree and 0.001 deg/sec respectively. Hence, the CDSF/EDO mated configuration exhibited passive attitude stability, precluding the need for any RCS jet attitude control which would perturb the micro-g environment. Results of ballistic coefficient determination and orbital lifetime analysis for the two configurations studied demonstrated that a 25 day CDSF/EDO mission in a gravity gradient stabilized flight mode would not require a reboost maneuver.

In general, the microgravity environment results were quite similar to those obtained and presented for the nominal mated CDSF/Orbiter analysis performed. The feathered solar array configuration exhibited the more favorable passive stability characteristics. However, the sun-tracking solar array CDSF/EDO configuration was seen to also not to exceed the $\pm$ 5 degree acceleration vector direction requirement.

While the particular CDSF/EDO configuration described in this section exceeded the one micro-G magnitude requirement, the alternative configuration described in section 5.2.1.1 addressed an option for achieving a one micro-G steady-state acceleration level.

EDO SUMMARY

THE CDSF CREW–TENDED CONFIGURATION HAS A STABLE STS TAIL DOWN LVLH FLIGHT MODE WITH ATTITUDE ERROR RATES BELOW 0.01 DEG/SEC FOR SUN–TRACKING SOLAR ARRAYS AND BELOW 0.001 DEG/SEC FOR FEATHERED SOLAR ARRAYS.

ATTITUDE CONTROL AND ORBITAL DECAY CHARACTERISTICS WERE COMPARABLE WITH THOSE OBTAINED FOR THE NOMINAL ORBITER. FOR THE HORIZONTALLY MATED CDSF, A STEADY STATE ENVIRONMENT OF UP TO 4 MICRO–G's IS SENSED IN THE CDSF LAB, RESULTING PRIMARILY FROM CDSF–COMPOSITE CENTER OF MASS OFFSETS.

A 25 DAY CDSF/EDO MISSION IN A GRAVITY GRADIENT LVLH FLIGHT MODE DOES NOT REQUIRE AN ALTITUDE REBOOST MANEUVER, INDEPENDENT OF THE SOLAR ARRAY ORIENTATION MODE.

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5.2.2. FREE FLYER MISSION

FREE FLYER MISSION MICROGRAVITY ENVIRONMENT CONSIDERATIONS

This section will address the flight mode stability considerations which will be used to define the CDSF stability and control system. To maintain a one micro-G environment for a required 30 day period for experiment operation will require a passive spacecraft attitude stability approach. STS rendezvous and TDRSS communications will require onboard precision attitude maintenance and knowledge for their respective operations. As will be shown, the size, articulating operation, and orientation of the solar arrays are dominant considerations for the choice of a CDSF configuration that satisfies both magnitude and direction requirements for allowable acceleration limits.

The consideration of the migration of the center of mass between free-flyer and STS attached missions will also be addressed.

FREE FLYER MISSION MICROGRAVITY ENVIRONMENT CONSIDERATIONS

PASSIVE GRAVITY GRADIENT STABILIZATION IS KEY CONSIDERATION

- PRECISION ORIENTATION MAINTENANCE REQUIRED FOR STS RENDEZVOUS
- PRECISION ORIENTATION KNOWLEDGE REQUIRED FOR TDRSS COMMUNICATIONS

SOLAR ARRAY SIZE AND ORIENTATION DOMINATES CONFIGURATION DEFINITION GEOMETRY

- BLANKET AREA DRAG CONTRIBUTION
- ARTICULATION DYNAMICS
- OUT OF PLANE INERTIA PROPERTIES

CDSF C.G. LOCATION COMMONALITY BETWEEN FREE-FLYER AND MAN-TENDED OPERATIONAL CONFIGURATIONS

- MICRO-G MAGNITUDE AND DIRECTION CONSIDERATION

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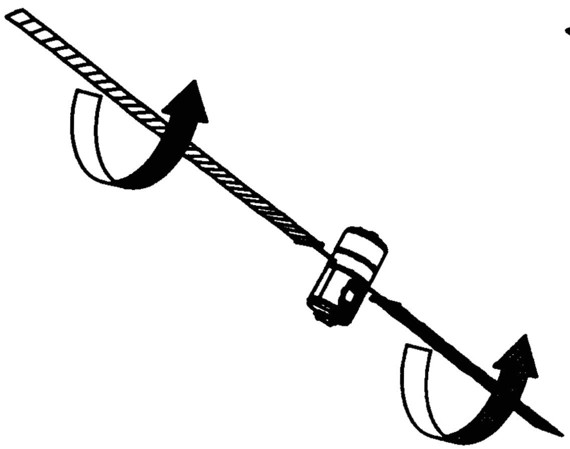
5.2.2.1. PASSIVE STABILIZATION

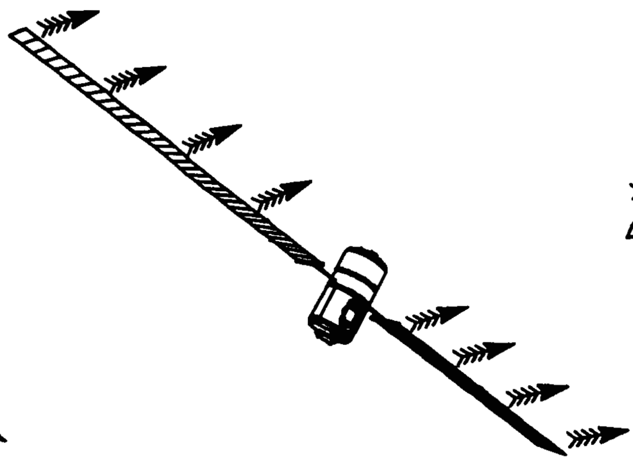
FREE FLYER SOLAR ARRAY ORIENTATION OPTIONS

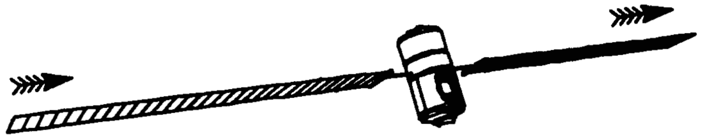
The CDSF microgravity environment is influenced by the solar array orientation by virtue of the contribution of aerodynamic drag to the overall sensed acceleration level. Three array orientations were studied : 1) sun-tracking, 2) feathered arrays perpendicular to the orbit plane, and 3) feathered arrays along the velocity vector. The sun-tracking configuration was found to increase the drag and hence increase the sensed micro-g level. The feathered options, while decreasing the available power for a fixed array area, resulted in a better microgravity environment. With the arrays oriented along the velocity, the best overall results were observed due to favorable roll-yaw stability characteristics.

FREE FLYER SOLAR ARRAY ORIENTATION OPTIONS

SUN TRACKING ARRAYS | **FEATHERED ARRAYS POP** | **FEATHERED ARRAYS VBAR**







BEST APPROACH FOR FREE FLYER MICRO-G ACCOMMODATION

ARRAYS INERTIALLY POINTED TO SUN, ROTATING WITH RESPECT TO THE SPACECRAFT.

ARRAYS ORIENTED WITH THEIR NORMAL PERPENDICULAR TO V.

VARTFEAFF

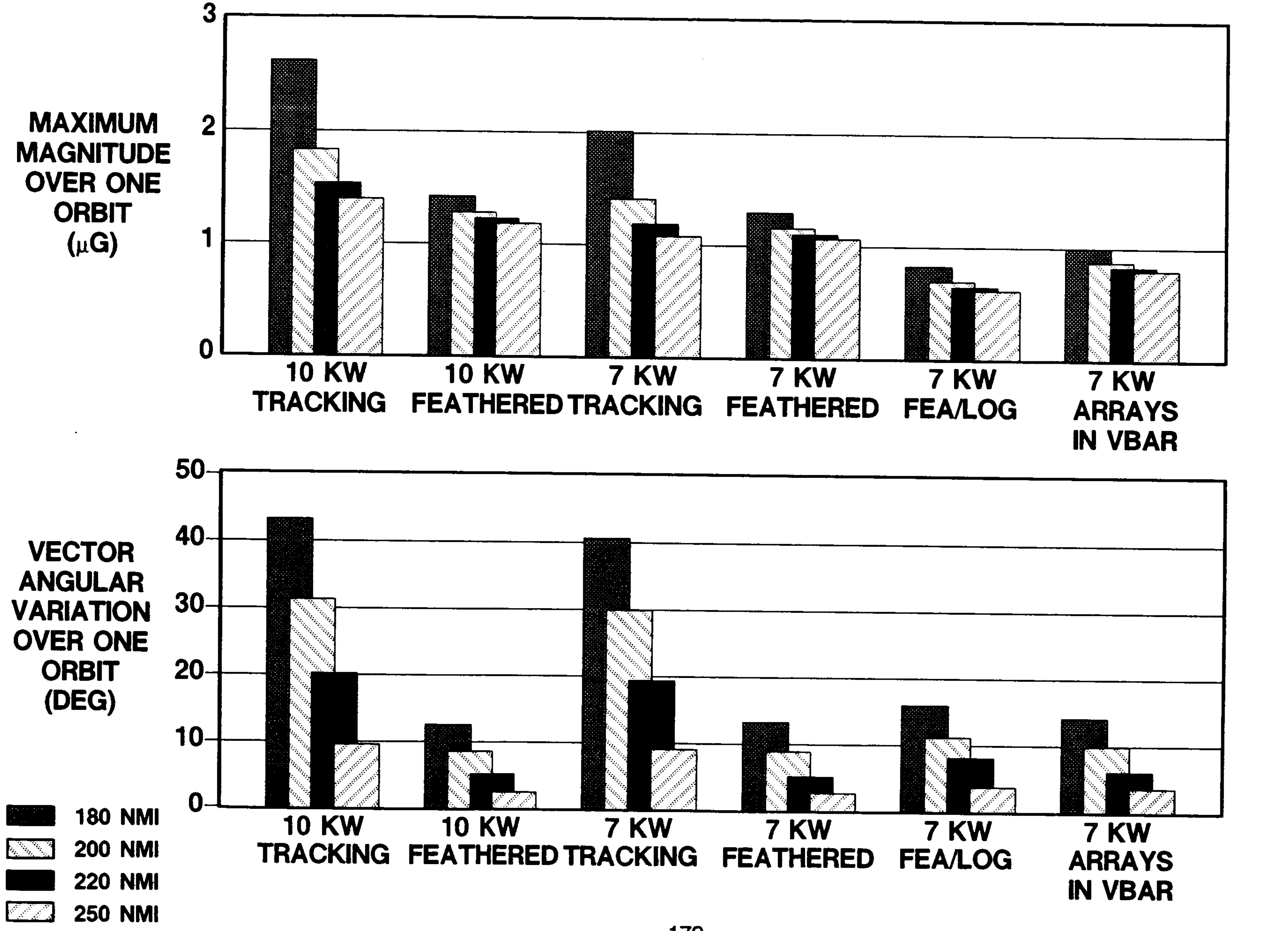
STEADY STATE MICROGRAVITY FREE FLYER CONFIGURATIONS

A parametric study of micro-g sensitivity to altitude for the CDSF free flyer configuration was performed. Various sized arrays were analyzed in both feathered and sun-tracking modes to establish trade-off parameters between sensed acceleration levels and power generation capabilities. Both micro-g magnitude as well as variation in micro-g direction were studied.

For a given power generation capacity, the sun-tracking mode sensed acceleration levels always exceeded the feathered mode. For example, the 7 kW tracking free-flyer configuration sensed a 2 micro-g acceleration at 180 Nm altitude vs 1.3 micro-g for the feathered POP option, and only 1.0 micro-g for the feathered v-bar option. Results were similar when comparing micro-g direction variation. For example, the 7 kW sun-tracking option sensed acceleration direction varied by as much as 40 degrees at 180 Nm altitude, whereas the feathered options varied by less than 15 degrees.

The sensed acceleration direction variation was more sensitive to altitude than was the acceleration magnitude. The 7 kW arrays oriented in the V-bar direction exhibited a sensed acceleration, magnitude that varied only from 1.0 to 0.085 micro-g's over the altitude region spanning 180 to 250 Nm. On the other hand for the same configuration, micro-g direction variation went from 15 degrees at 180 Nm to less than 3 degrees at 250 Nm.

Steady State Microgravity
FREE FLYER CONFIGURATIONS



CDSF FREE FLYER FLIGHT MODE CHARACTERISTICS

The free flyer flight mode characteristics were evaluated in order to determine whether or not attitude control devices would be required. Considering the 7 kW power generation configuration, both the POP array orientation as well as the V-bar orientation required a gravity gradient boom for pitch stability. The V-bar orientation, however, was inherently stable in roll-yaw, with oscillations on the order of plus or minus 3 degrees over an orbit. The arrays POP orientation required a momentum wheel to achieve roll-yaw stability.

CDSF FREE FLYER FLIGHT MODE CHARACTERISTICS

- **ARRAYS PERPENDICULAR TO ORBIT PLANE WITH SOLAR BETA CORRECTION**
  - REQUIRES SIGNIFICANT CONTROL DEVICE (MOMENTUM WHEEL, CMG, RCS) FOR ROLL/YAW STABILITY
  - REQUIRES GRAVITY GRADIENT BOOM FOR PITCH STABILITY

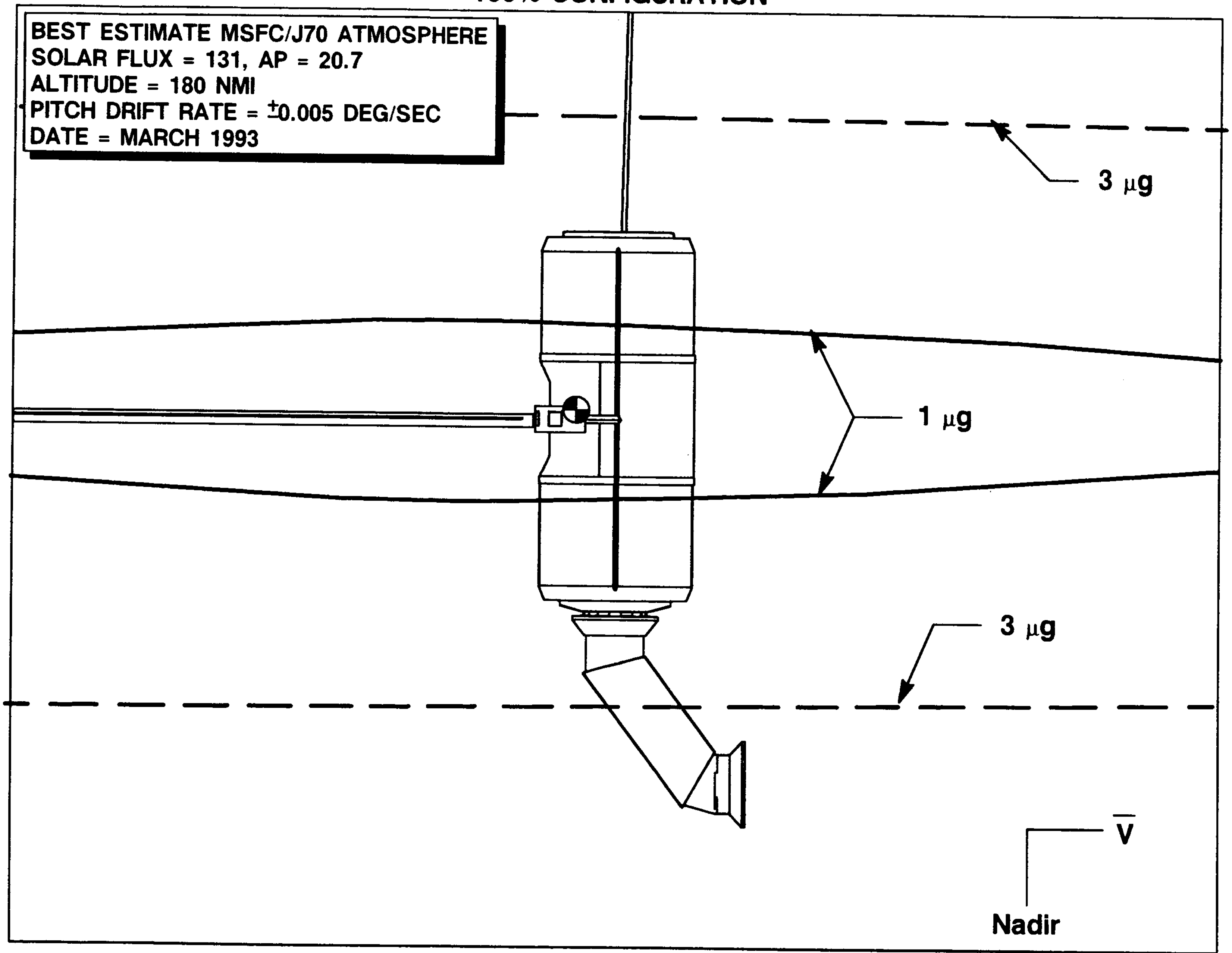
- **ARRAYS ALONG VELOCITY VECTOR WITH SOLAR BETA CORRECTION**
  - STABLE IN ROLL/YAW
  - REQUIRES GRAVITY GRADIENT BOOM FOR PITCH STABILITY

FREE FLYER STEADY STATE MICROGRAVITY CONTOURS

The free-flyer configuration was found to be passively stable with the gravity gradient boom extended along the minus nadir axis and the solar arrays trailing along the minus velocity vector direction. The steady state microgravity environment was then determined using a nominal atmosphere model at a 180 Nm altitude. The laboratory section of the CDSF module fell within the plus or minus 1 micro-g acceleration level contour.

Free Flyer Steady State Microgravity Contours

100% CONFIGURATION



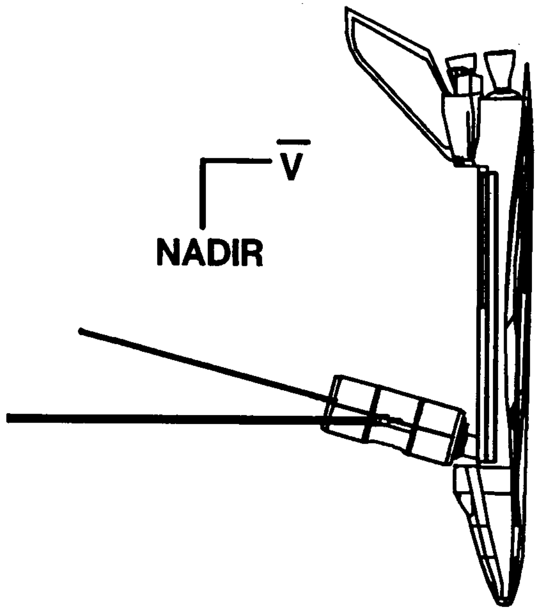
100%cdsf

PASSIVE FLIGHT STABILITY FOR MICRO-G ACCOMMODATION

Based on the analysis performed, a passively stable attitude was determined for both the CDSF/STS crew tended configuration and the CDSF free-flyer configuration. The free-flyer stable configuration required a gravity gradient boom oriented along nadir, and the solar arrays oriented along V-bar. The man-tended stable flight orientation is defined with the Orbiter nose down, wings POP, and the CDSF arrays oriented along V-bar.

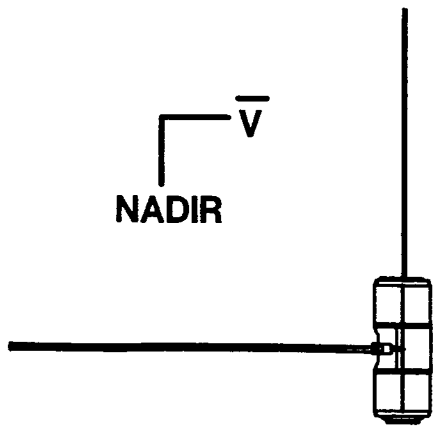
PASSIVE FLIGHT STABILITY FOR MICRO-G ACCOMMODATION

CREW-TENDED CONFIGURATION



- ORBITER NOSE TO NADIR
  - WINGS PERPENDICULAR TO ORBIT PLANE (POP)
- CDSF EXTENDED FROM CARGO BAY ($-\overline{V}$)
  - SOLAR ARRAYS ALONG –V

FREE FLYER



- GRAVITY GRADIENT BOOM EXTENDED ALONG NADIR
- SOLAR ARRAY ALONG $-\overline{V}$

CDSF SENSED ACCELERATION DIRECTION

An analysis was performed to determine the acceleration variation in sensed direction between the CDSF/STS mated configuration and the CDSF free-flyer configuration,

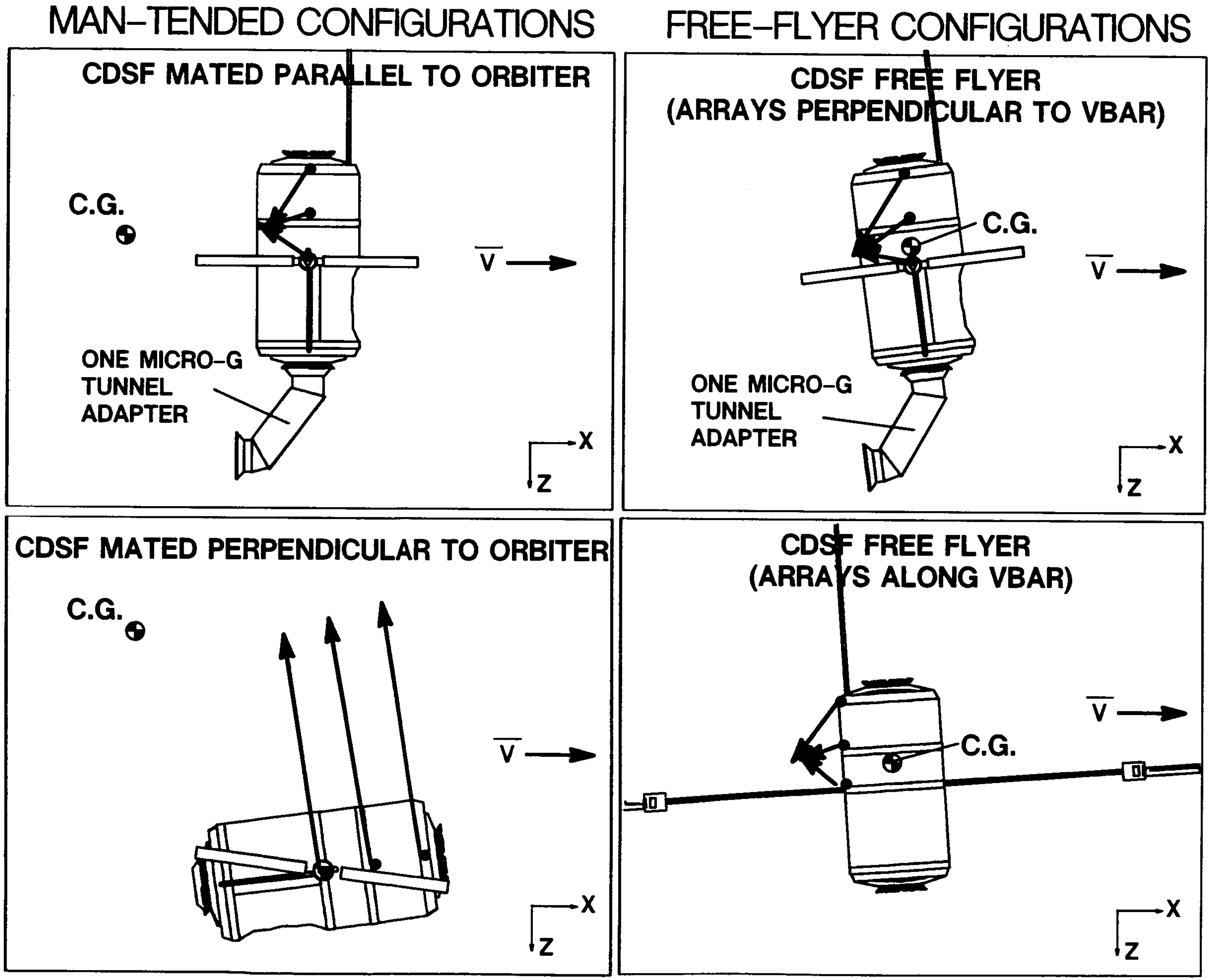
The purpose of the analysis was to understand and quantitatively assess the effect of center of mass migration between the STS crew-tended configuration microgravity environment and the free-flyer microgravity environment. Two CDSF/STS mated configurations were assessed. The first mated configuration aligned the CDSF parallel to the Orbiter cargo bay length. As discussed in Section 5.2.1.1, this configuration requires a tunnel adapter between the CDSF and the docking system interface to the Shuttle Orbiter for the purpose of obtaining a 1 micro-G sensed acceleration level. The second mated configuration aligned the CDSF perpendicular to the Orbiter cargo bay. The composite CDSF/STS center of mass is shown to be displaced from the the center of the CDSF laboratory section for both mated configuration by over 25 feet.

The differences in acceleration direction between the mated and the free-flyer modes show a significant difference for the CDSF/STS mated configuration with the CDSF aligned parallel to the cargo bay.

The free-flyer flight mode shown is a passively stable gravity gradient orientation. When compared to either the parallel or the perpendicular mated configurations, the variation between the free-flyer configuration and the mated parallel configuration is seen to be relatively insignificant because the c.g. migration is along the flight path direction. However, the perpendicular aligned CDSF in the mated STS configuration had a large Z-axis c.g. offset of nearly 20 feet which caused a large acceleration direction magnitude variation of over 80 degrees.

If the large variation in acceleration direction between the mated configuration and the free-flyer configuration causes concern between the consistency of experiment operation between the two flight modes, then the parallel aligned CDSF/STS crew-tended configuration is the preferred concept geometry. For the experiment that required acceleration direction consistency between the crew-tended and free-flyer mode, an alternative consideration is to implement gimbal mechanisms within the experiment hardware to account for the difference in flight mode variation.

CDSF SENSED ACCELERATION DIRECTION



NEWMGCOMP

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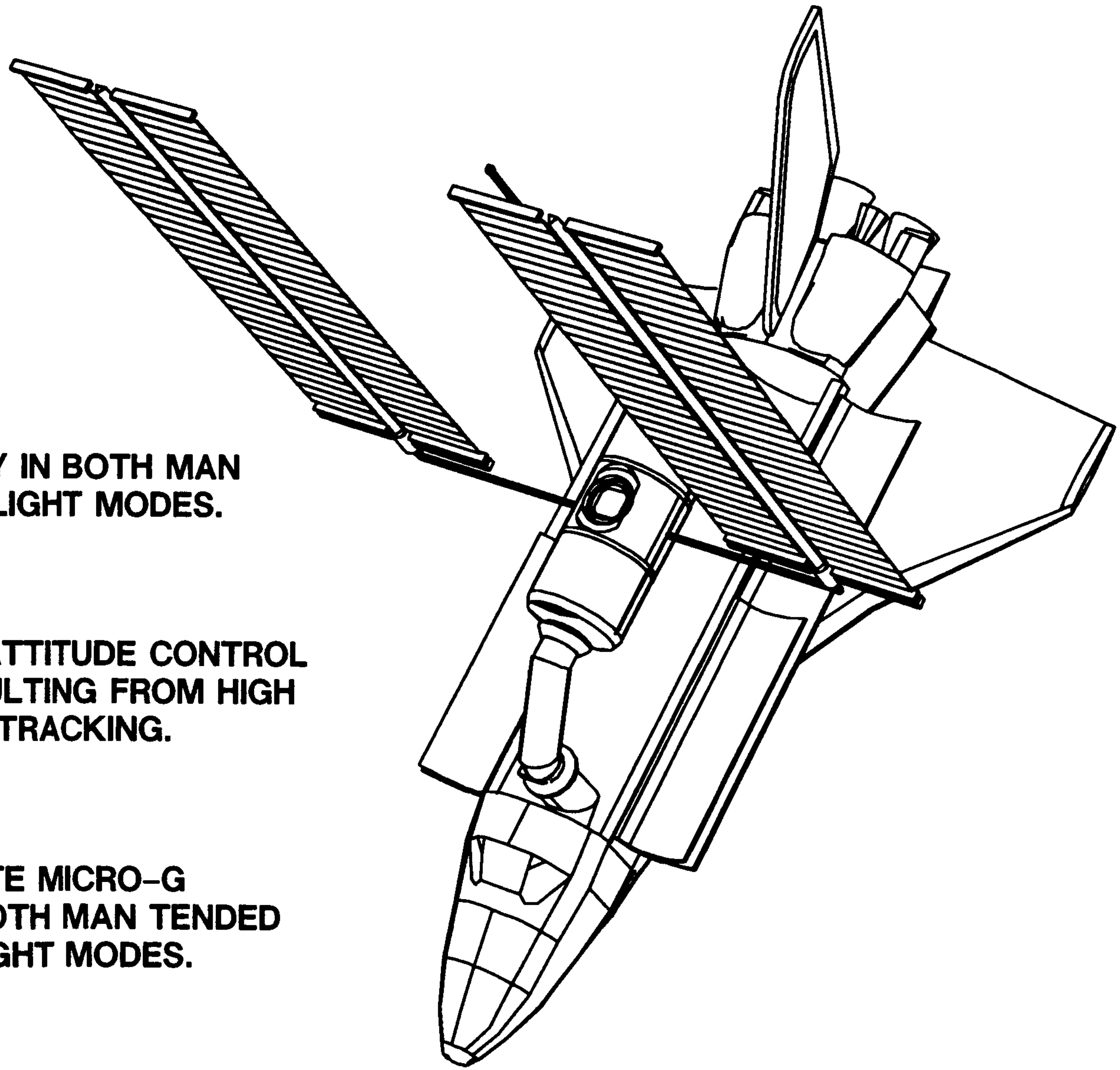
5.2.2.2. SOLAR ARRAY ORIENTATION DEFINITION

ARRAYS IN FOLDED CONFIGURATION

The conclusion of the solar array orientation assessment is that the CDSF arrays should be aligned along V-bar in a feathered orientation. This configuration definition meets both acceleration magnitude and direction requirements due primarily to : 1) feathering the arrays reduces drag induced sensed acceleration compared to sun-tracking arrays, 2) roll-yaw stability is achieved without the need for active attitude control or angular momentum absorption device, and 3) the solar beta angle tracking impact on attitude control is minimized when compared to the arrays oriented perpendicular to the orbit plane.

ARRAYS IN THE FOLDED CONFIGURATION



- ENHANCES STABILITY IN BOTH MAN TENDED AND FREE FLIGHT MODES.
- ELIMINATES LARGE ATTITUDE CONTROL REQUIREMENTS RESULTING FROM HIGH SOLAR BETA ANGLE TRACKING.
- MEETS STEADY STATE MICRO-G REQUIREMENTS IN BOTH MAN TENDED AND FREE FLYER FLIGHT MODES.

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6.0. SPACECRAFT CONCEPTS

CDSF CONFIGURATION CONCEPTS

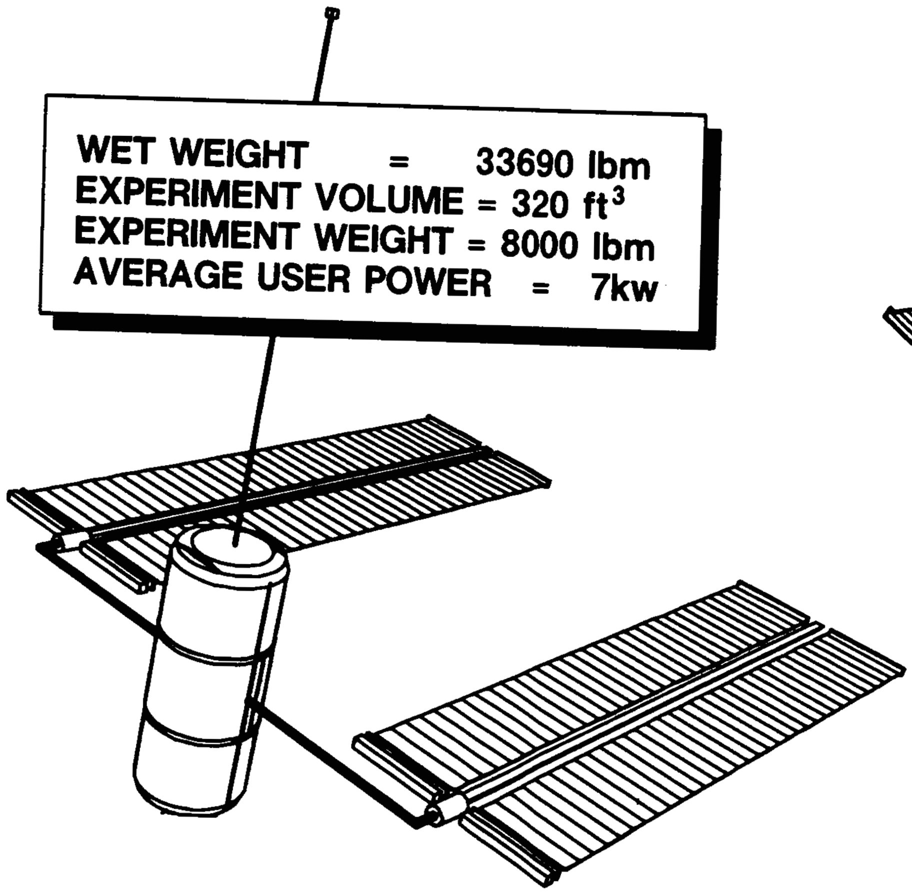
As stated earlier in this report, the objective of this NASA in-house study is to define two configuration concepts. This report section will define the overall configuration characteristics and provide subsystem descriptions for both concepts.

The two configurations generated from the configuration definition task of this study are depicted here. Concept #1 represents a configuration that addresses 100% of the Appendix B draft RFP requirements. Concept #2 is a reduced capability concept whose experiment volume capacity is only 20% of the RFP required capacity.

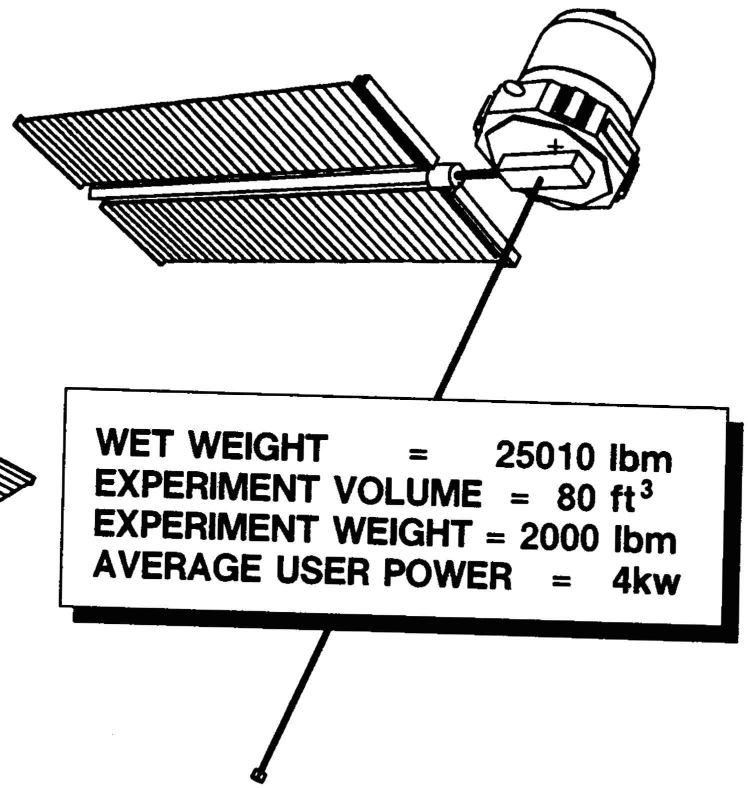
CDSF concept #1 is defined to weigh almost 34,000 pounds and can provide an average of 7 KW of user power to over 8000 pounds of experiments. It provides an experiment volume of 320 cubic feet. Power generation is provided by photovoltaic solar arrays and attitude, altitude, communication, data handling, temperature and environmental control is provided by on board systems located inside the facility structure. A gravity gradient boom is used to help maintain passive flight attitude stabilization.

Concept #2 is the reduced capability configuration and is composed of a small pressurized experiment module connected to a spacecraft bus. The pressurized module accommodates 80 cubic feet of experiments weighing up to 2000 pounds. The attached spacecraft bus provides 4 KW of user power to the experiments as well as providing other subsystem utility functions. Thermal control for the experiment module is provided by a pumped single phase fluid loop system using body mounted radiators in the pressurized module.

CDSF CONFIGURATION CONCEPTS



CONCEPT #1



CONCEPT #2

COMPOSITE

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6.1. REQUEST FOR PROPOSAL REQUIREMENTS BASELINE (100% REFERENCE)

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CDSF CONCEPTUAL DESIGN REQUIREMENTS AND ASSUMPTIONS

Several major requirements and assumptions were considered in the concept definition of the CDSF. All tanks and systems were sized such that the CDSF could survive for three years without servicing to prevent the possibility of facility loss in case of a stand down of the STS fleet. The CDSF will be pressurized to 14.7 pisa per shuttle visit and must maintain nominal atmospheric pressure in the free flyer mode with an assumed leak rate of 0.5 lbm/day. Crew-tended operations will occur only when the CDSF is attached to the shuttle which will handle all life support requirements. Two to three crew members can work simultaneously in the CDSF for up to 25 days during an EDO mission. The CDSF does not need to provide safe haven capability for the crew because all operations are in the shuttle attached mode. however, all NSTS safety requirements must be met.

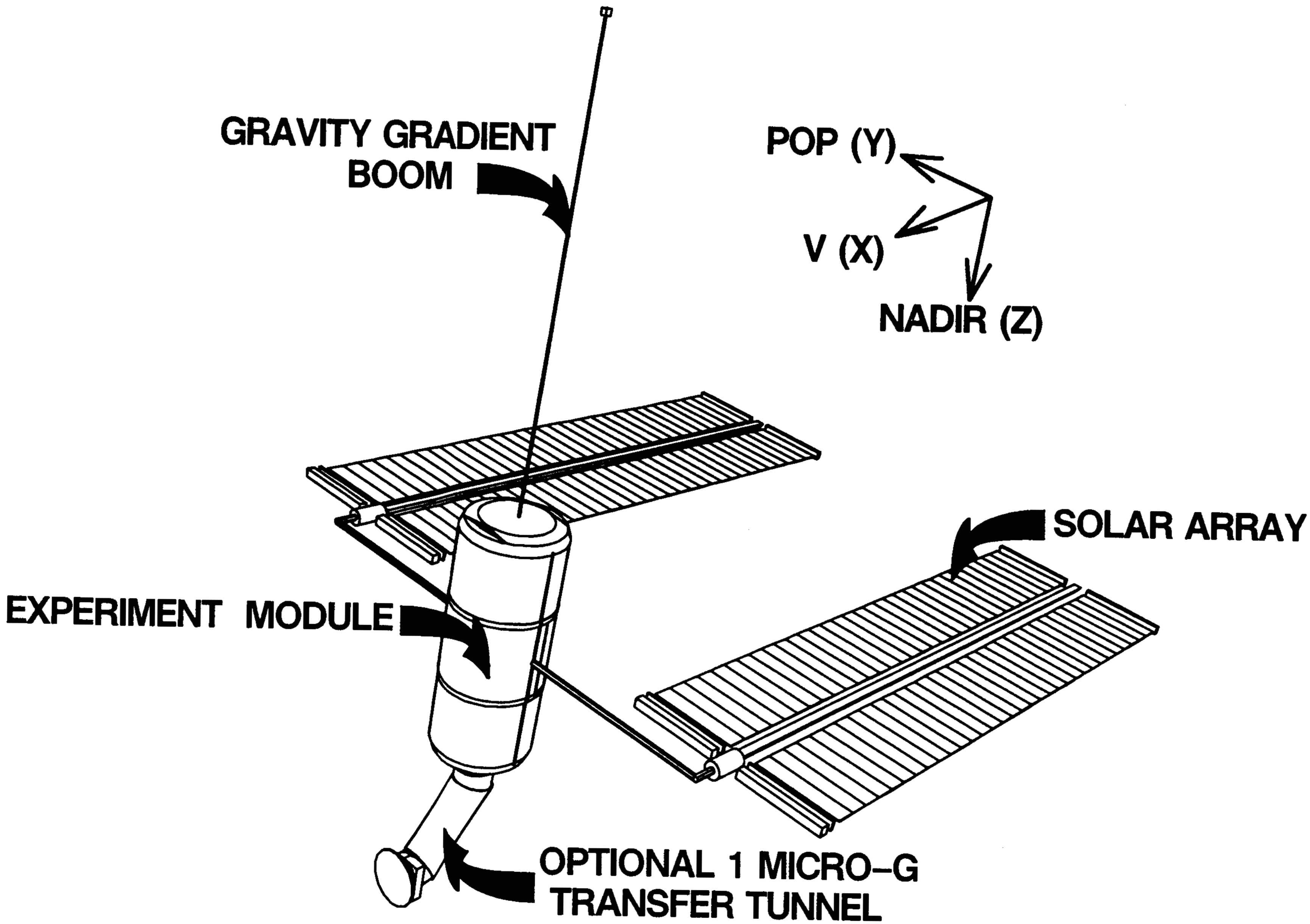
CDSF CONCEPTUAL DESIGN REQUIREMENTS AND ASSUMPTIONS

- CDSF 3–YEAR ORBITAL LIFE WITHOUT SERVICING
- CABIN ATMOSPHERE MAINTAINED AT 14.7 psia, FREE FLYER LEAK RATE OF .5 LB/DAY
- ONE REPRESSURIZATION REQUIRED PER SHUTTLE VISIT
- CREW–TENDED OPERATIONS ACCOMPLISHED WHILE ATTACHED TO SHUTTLE
- LIFE SUPPORT REQUIREMENTS SUPPORTED ENTIRELY BY SHUTTLE SYSTEM (A)
- INCLUDES EDO MISSIONS UP TO 25 DAYS
- SIZED FOR 2 CREW MEMBERS TO WORK SIMULTANEOUSLY IN CDSF
- CDSF DOES NOT PROVIDE SAFE HAVEN CAPABILITY

CDSF CONCEPT #1 FREE FLYER CONFIGURATION

The CDSF #1 free flyer configuration is made up of several components including the experiment module, the solar arrays and the gravity gradient boom. The experiment module is a 12.5' diameter 30' long pressurized cylinder that contains the pressurized elements. Attached to the experiment module are two solar arrays that are deployed in the "folded" configuration where the longitudinal axis of the arrays are parallel with the velocity vector and trailing the experiment module. The gravity gradient boom is attached to the top of the experiment module and points away from the Earth in the free flyer mode. An optional 1 micro-G transfer tunnel adapter can be attached to the berthing port on the bottom of the experiment module to improve sensed acceleration levels while mated to the orbiter. The CDSF free flyer has a gravity gradient stable orbital flight attitude where nadir is aligned along the longitudinal axis of the experiment module and gravity gradient boom and the velocity vector is aligned with the longitudinal axis of the feathered solar arrays.

CDSF CONCEPT #1 FREE FLYER CONFIGURATION

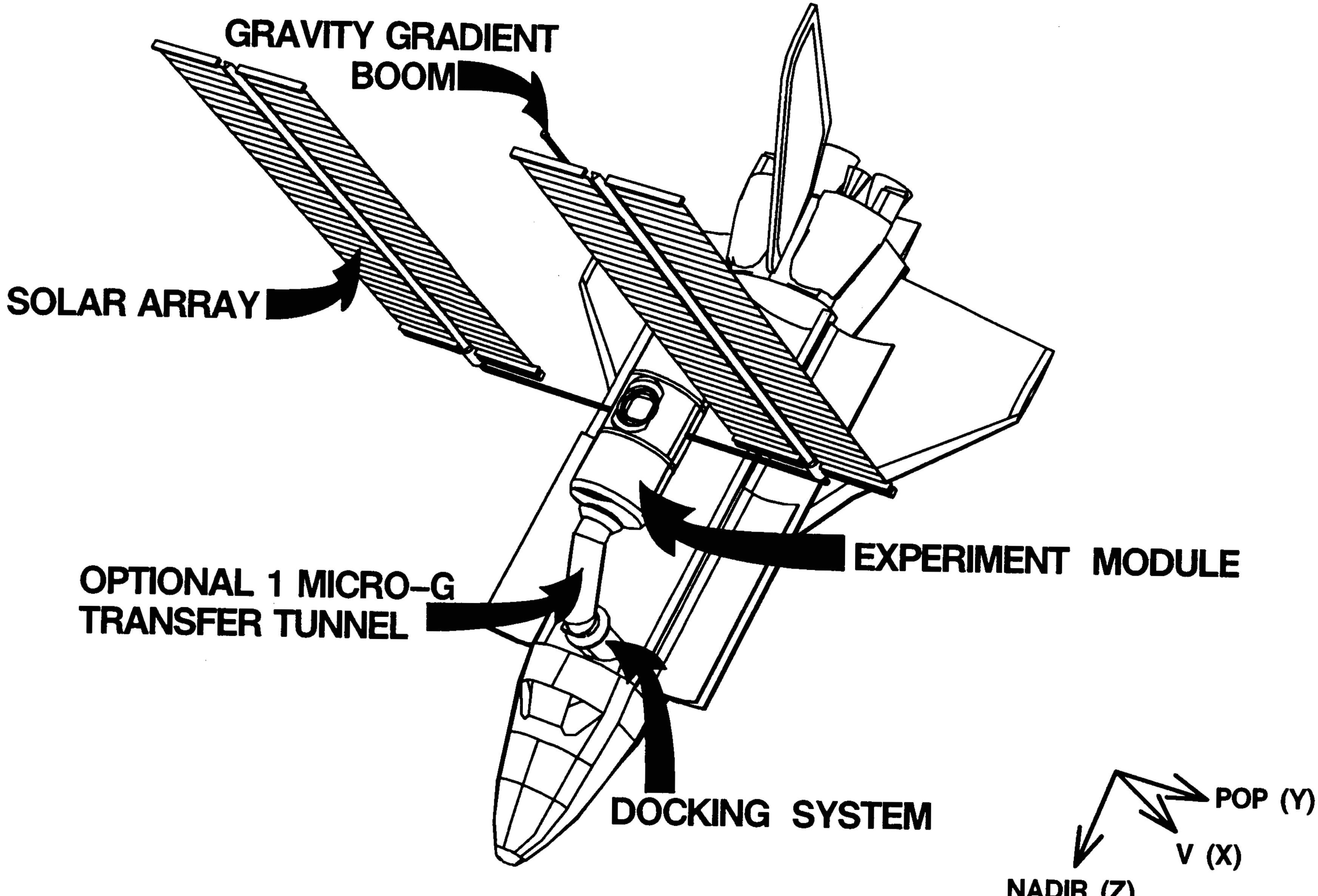


FREE100

CDSF CONCEPT #1 MATED CONFIGURATION

The CDSF #1 mated configuration is achieved by berthing the CDSF with the orbiter RMS to the orbiter docking system. Depending on whether the optional 1 micro-G tunnel is used, the gravity gradient boom or solar arrays must be rotated to provide proper clearance, stability and power characteristics. The mated configuration flies in a gravity gradient stable flight mode with the nose of the orbiter pointing towards the Earth, the bottom of the orbiter into the wind and the orbiter wings perpendicular to the orbit plane.

CDSF CONCEPT #1 MATED CONFIGURATION



MATE100

CDSF CONCEPT #1 WEIGHT ALLOCATION SUMMARY

Subsystems in the CDSF were conceived to establish weight allocations so that maximum experiment weight based on orbiter 102 lift capability could be defined. Orbiter 102 (Columbia) has extra structure and other design differences as compared to the remaining STS orbiters that limit its lift capability to 37,630 pounds to an orbital altitude of 160 n.mi at an inclination of 28.5 degrees. The largest weight definition is the structural elements of the CDSF followed by the power and propulsion systems. It should be noted that the weight definition for the propulsion system reflects a partially wet system. The propulsion system is defined to use water as the propellant. During the initial deployment flight of the CDSF, 1200 pounds of water is transferred from the orbiter as fuel cell by-products. Taking into account the weight of the docking system, retention devices, associated support equipment and weight allocation for payload specialists, OV-102 could lift a CDSF with almost 8000 pounds of experiments to a deployment altitude of 160 n.mi. This represents an experiment rack outfitting of about 100% assuming a rack density of 25 pounds of experiment per cubic foot of rack space.

CDSF CONCEPT #1 WEIGHT ALLOCATION SUMMARY

ITEM DESCRIPTION	WEIGHT (LBS)
STRUCTURES	12370
THERMAL	1857
POWER	3910
ECLSS	2245
COMMAND & DATA HANDLING	410
GUIDANCE, NAVIGATION & CONTROL	190
PROPULSION SYSTEM[1]	3542
EXPERIMENTS[2]	7966
SUBTOTAL	32490
DOCKING SYSTEM	2440
P/L RETENTION	1500
MISC. ASE	300
P/L SPECIALIST	900
TOTAL LAUNCH WEIGHT	37630

[1] 1200 LBMS OF WATER TRANSFERRED FROM ORBITER

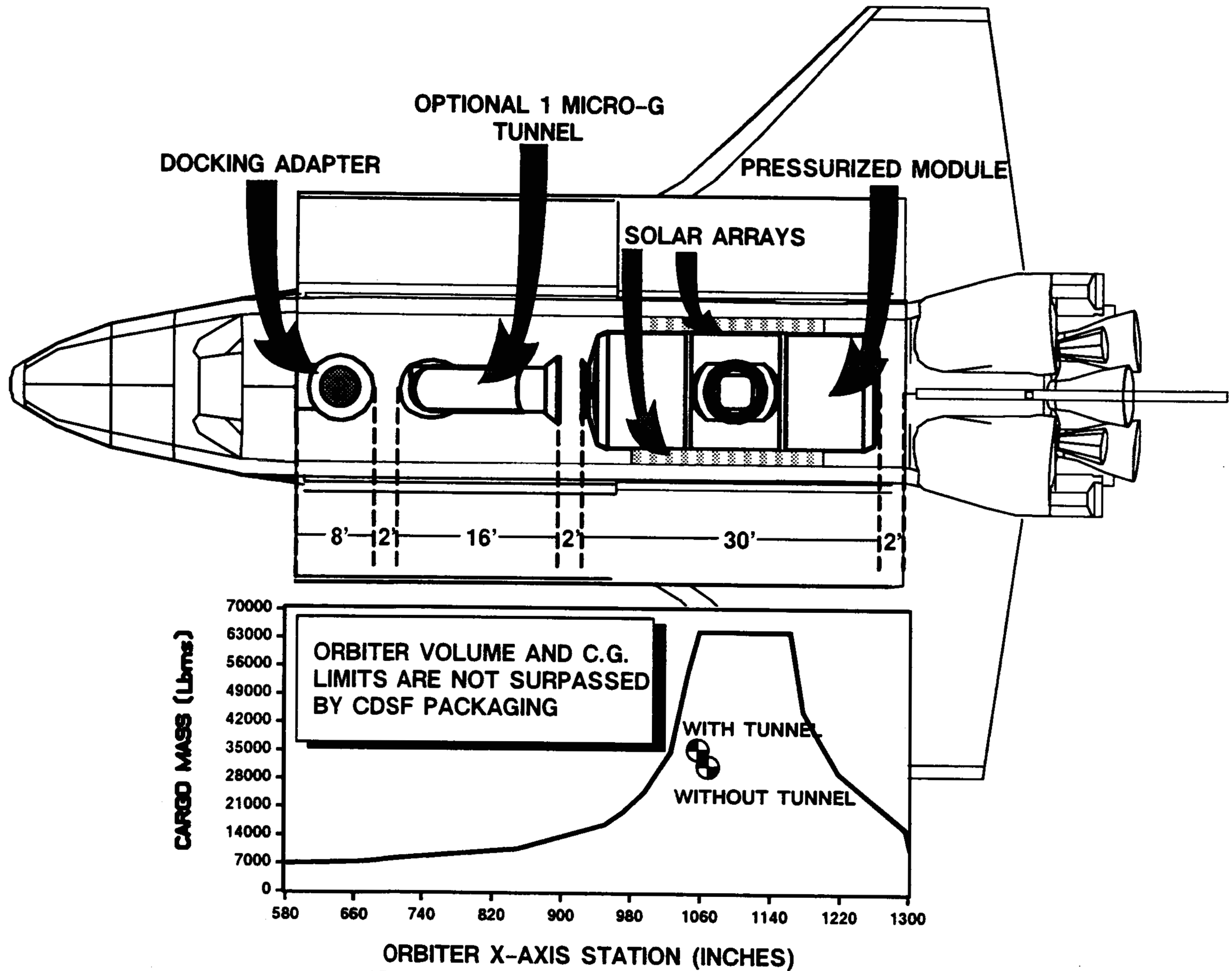
[2] 100% EXPERIMENT OUTFITTING

WSUM89

CDSF CONCEPT #1 CARGO BAY PACKAGING

An orbiter packaging analysis was performed for the CDSF. The orbiter cargo bay is 60 feet long and has a dynamic payload packaging envelope that is 14.5 feet in diameter. All cargo elements must have 2 feet of space between them to allow for RMS runaway and the combined cargo center of gravity must fall within the operational limits specified by the STS. The docking adapter is attached to the forward bulkhead and extends 8 feet into the cargo bay with a two foot space between it and the 16 foot long optional one micro-G tunnel. Two feet further down the cargo bay is the CDSF module which is 30 feet in length and 12.5 feet in diameter. The external batteries and packaged solar arrays are configured such that the experiment module just fits into the 14.5' diameter dynamic envelope. Two feet of empty space remains aft of the experiment module for aft bulkhead clearance. Using the latest STS provided cargo mass center of gravity location requirement, it was shown that the CDSF packaging did not surpass cargo C.G. limits for a CDSF concept definition with or without the optional one micro-G tunnel.

CDSF CONCEPT #1 CARGO BAY PACKAGING



X-AXIS C.G. ENVELOPE FOR STS CARGO

PACK100

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6.1.1. LAYOUT DESCRIPTIONS

CDSF LAYOUT DESCRIPTIONS

This section provides layout descriptions of the CDSF pressure vessel design and the internal systems hardware accommodation.

6.1.1.1. PRESSURE VESSEL DESIGN

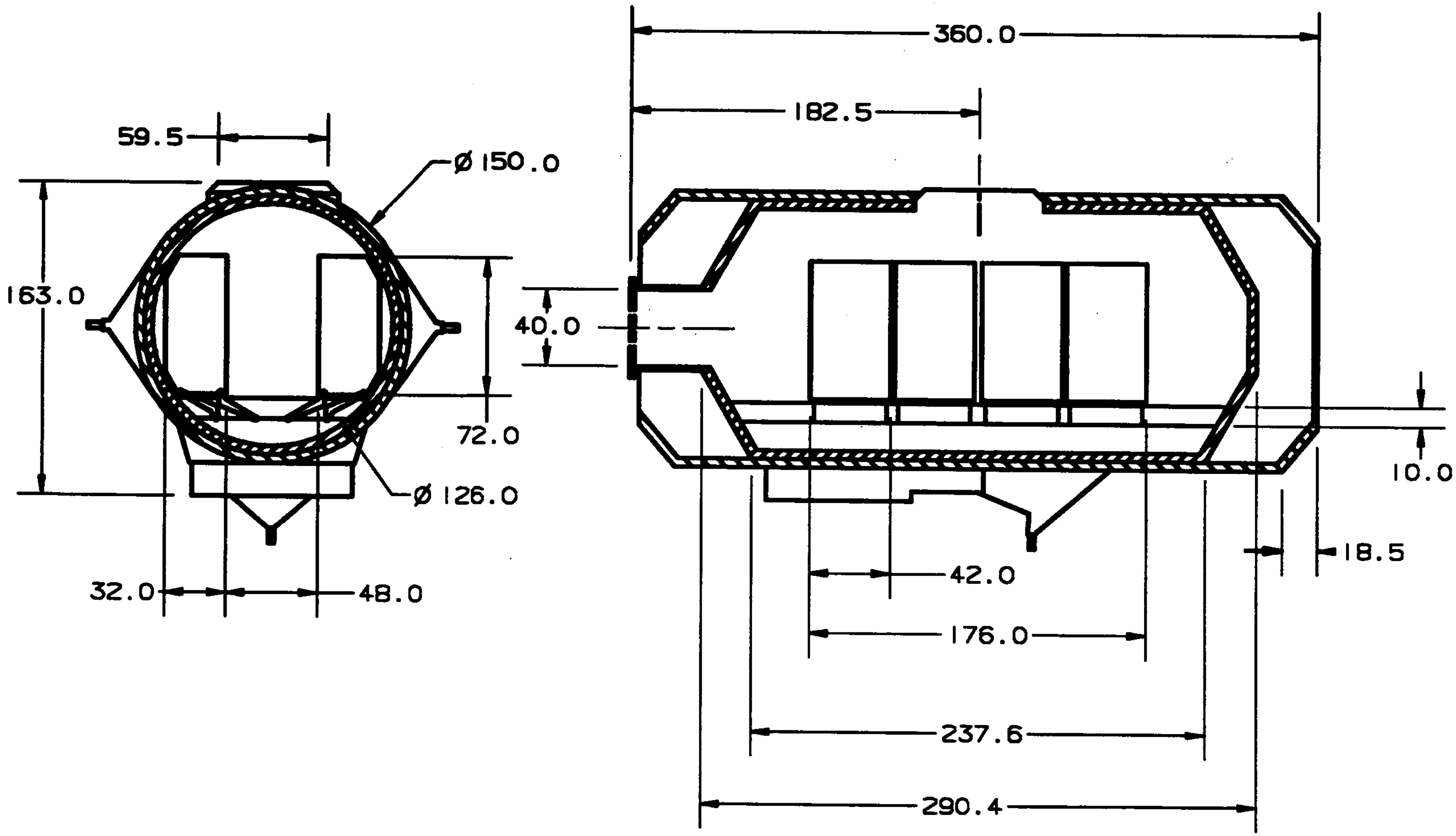
CDSF PRESSURE VESSEL DESIGN

The general configuration includes a pressure shell diameter of 10.5 feet (internal) and length of 24 feet (includes conical end domes) and a total module length of 30 feet and external diameter of 12 feet. The pressure shell sizing was determined primarily by experimental equipment volume and internal subsystem volume. Body-mounted radiators, micrometeoroid/debris shielding, pressure shell, and primary structure extend the external module diameter to 12 feet. Due to requirements of deployable solar arrays and attachment of battery assemblies external to the pressure shell, the pressure shell was offset from centerline of the 14.5 foot diameter payload envelope within the shuttle cargo bay. With such a configuration the stowed solar arrays and battery assemblies could be stowed beneath the module (see section 6.1.1.2). These external assemblies were a driving factor in determining the 12 foot external diameter of the module.

CDSF CONCEPT #1 EXPERIMENT MODULE AND RACK DIMENSIONS

(DIMENSIONS IN INCHES)

C-3



CDSF#1DIMENSIONS

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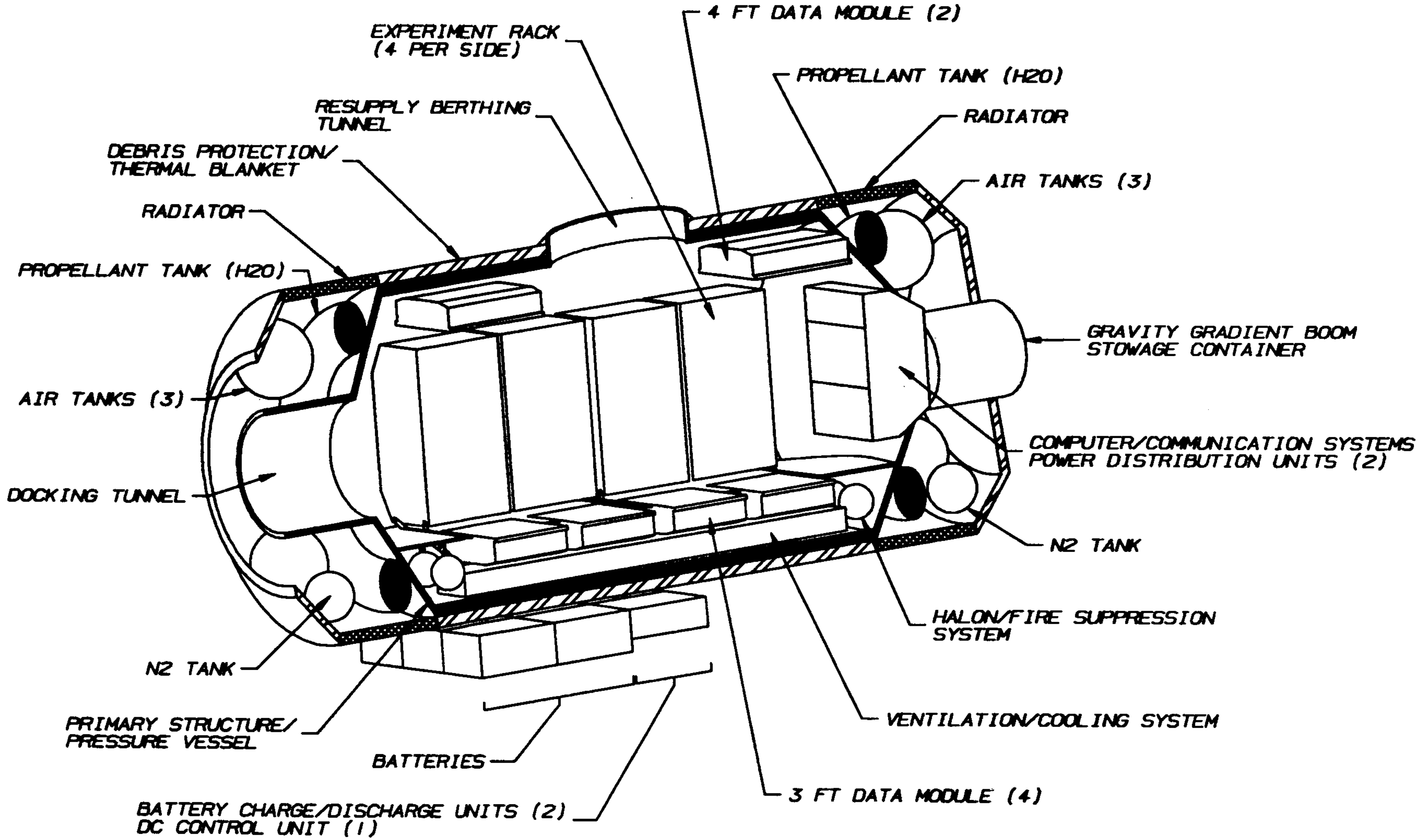
6.1.1.2. SYSTEMS ACCOMMODATION

CDSF SYSTEM CONFIGURATION

The primary driver within the integration scheme revolved around the stowage of the experiment racks. A total of 300 cubic feet of experimental volume was required. This volume was to be clustered as close as possible to the center of gravity of the module in order to accommodate microgravity requirements. Eight standard double racks were allotted to meet the volume requirement and the racks were arranged in two rows of four centered on the port and starboard sides of the module in close proximity to the module's center of gravity. Four 3 ft. and three 4ft. data modules were located in the floor and ceiling support the experiment racks. Computer/communication systems, power distribution units, ventilation/cooling system, fire suppression system and cabling were located in the end cones and beneath the floor.

Located external, at each end, of the pressurized volume is a segmented, torus shaped propellant tank. The volume of each tank is sufficient for the total fuel load, allowing the fuel (water) to be positioned around the torus or end to end on the spacecraft to assist in maintaining the center of mass in the desired location. Spherical air tanks are also located external to the pressurized volume for safety considerations.

CDSF CONCEPT #1
SYSTEM CONFIGURATION

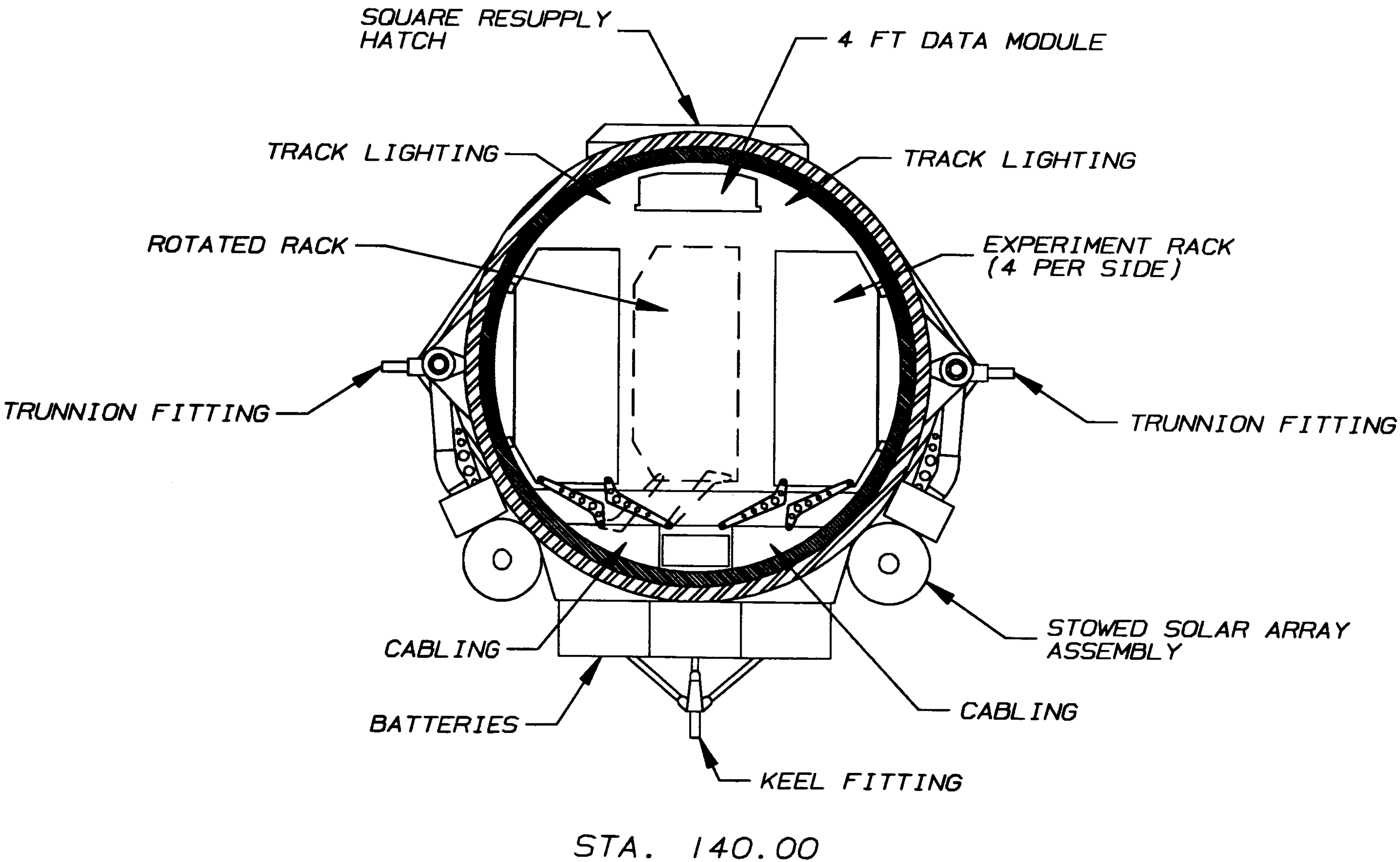


CDSF#1SC

CDSF SYSTEMS LAYOUT

Batteries and battery charge/discharge units were attached beneath the module. The stowed solar array arms and assemblies utilize the remaining space beneath the module. All internal components are conceived to be replaceable on orbit. This transverse section view shows the attachment mechanism of the experiment racks. The clearance of an experiment rack rotated out into the CDSF aisle for replacement or maintenance is depicted.

CDSF CONCEPT #1
TRANSVERSE SECTION



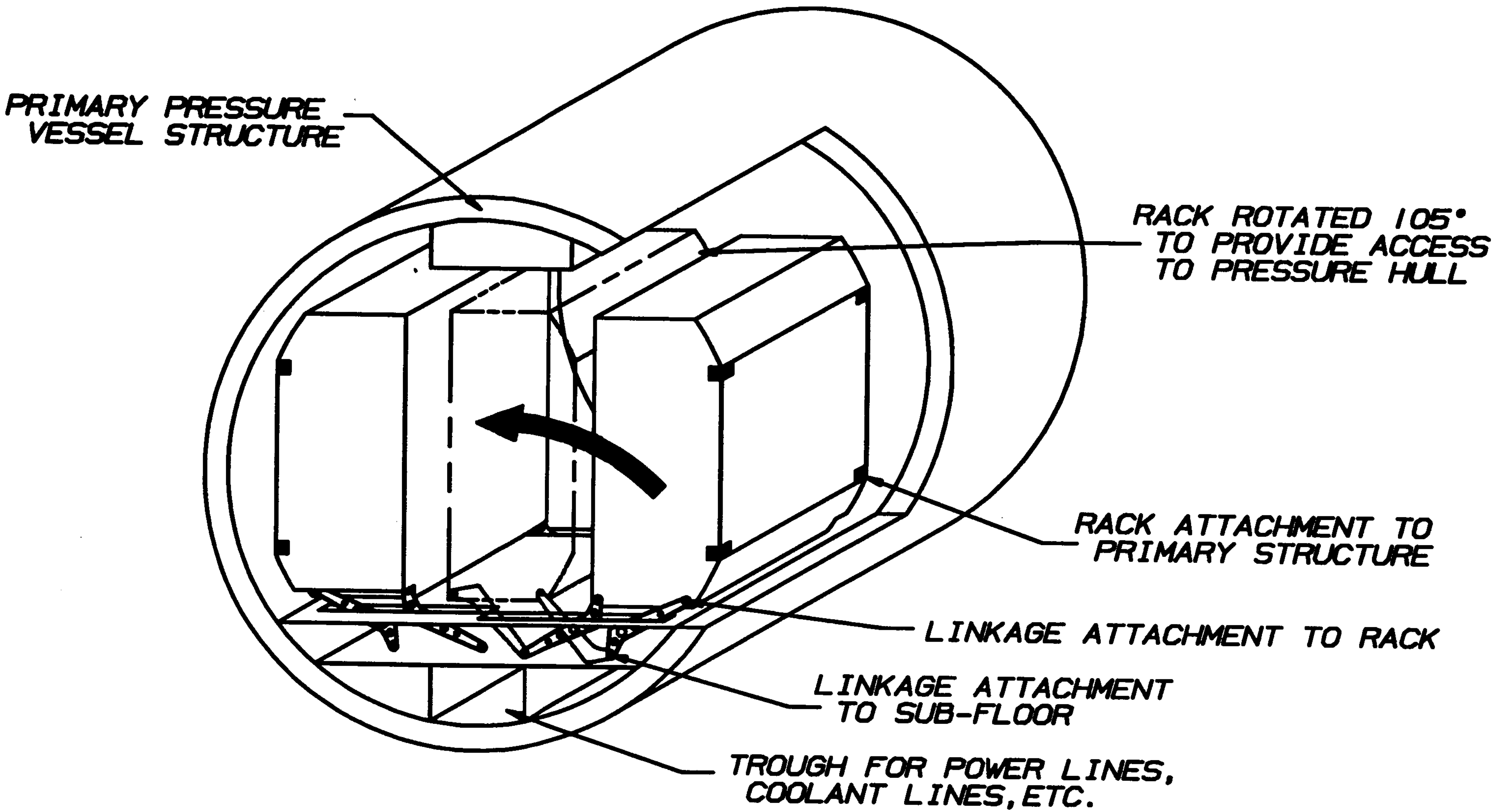
CDSF#1TS

4 BAR RACK LINKAGE CONCEPT

Internal to the spacecraft the Experiment Racks are attached to the pressure shell structure at four points and through a four bar linkage system. To obtain access to the pressure shell behind the rack or to remove a rack an astronaut would release the four point latch system and rotate the rack into the aisle. To remove the rack it would be entirely released from the four bar link system and maneuvered through the access hatch.

The racks are clustered in groups of two on four support trays that rotate into the main isle using the four bar linkage arrangement. The rotating trays allow for quick access to the rear of the racks and pressure vessel in cases of emergency.

4 BAR RACK LINKAGE CONCEPT



4BAR

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6.1.2. SYSTEMS DESCRIPTIONS

SYSTEMS DESCRIPTIONS

Detailed descriptions of the major subsystems of the CDSF are presented.

6.1.2.1. ENVIRONMENTAL CONTROL SYSTEM

CDSF CONCEPTUAL DESIGN REQUIREMENTS AND ASSUMPTIONS

Several major requirements and assumptions were considered in the definition of the CDSF environmental control system. All tanks and systems were sized such that the CDSF could survive for three years without servicing to prevent the possibility of facility loss in case of STS stand down. The CDSF will be pressurized to 14.7 psia per shuttle visit and must maintain nominal atmospheric pressure in the free flyer mode with an assumed leak rate of 0.5 lbm/day. Crew–tended operations will occur only when the CDSF is attached to the shuttle which will handle all life support requirements. Two crew members will work simultaneously in the CDSF for up to 25 days in the case of an EDO mission.

CDSF CONCEPTUAL DESIGN REQUIREMENTS AND ASSUMPTIONS

- CDSF 3–YEAR ORBITAL LIFE WITHOUT SERVICING
- CABIN ATMOSPHERE MAINTAINED AT 14.7 psia, FREE FLYER LEAK RATE OF .5 LB/DAY
- ONE REPRESSURIZATION REQUIRED PER SHUTTLE VISIT
- CREW –TENDED OPERATIONS ACCOMPLISHED WHILE ATTACHED TO SHUTTLE
- LIFE SUPPORT REQUIREMENTS SUPPORTED ENTIRELY BY SHUTTLE SYSTEM
- INCLUDES EDO MISSIONS UP TO 25 DAYS
- 2 CREW MEMBERS CAN WORK IN CDSF
- INTERNAL PRESSURIZED VOLUME OF 1800 CUBIC FEET

CDSF ENVIRONMENT CONTROL DESIGN DESCRIPTION

A description of the CDSF environment control system is given for atmosphere control and supply, trace contaminant control, ventilation, and fire detection and suppression. The CDSF atmosphere is supplied by oxygen and nitrogen from high pressure storage. Trace contaminant control is accomplished with a monitoring system and catalytic oxidation and filters. The CDSF ventilation system connects into the Orbiter's air revitalization system during mated operations and can be run in a free flyer mode to remove contaminants. The CDSF fire detection and suppression system includes detection and pyro control sub-assemblies, a fire extinguisher sub-assembly, a portable fire extinguisher, and three emergency breathing packs.

CDSF ENVIRONMENTAL CONTROL DESIGN DESCRIPTION

Atmosphere control and supply
- High pressure storage of oxygen and nitrogen
- Atmosphere monitoring and control system

Trace contaminant control
- Monitoring system
- Catalytic oxidation and filters

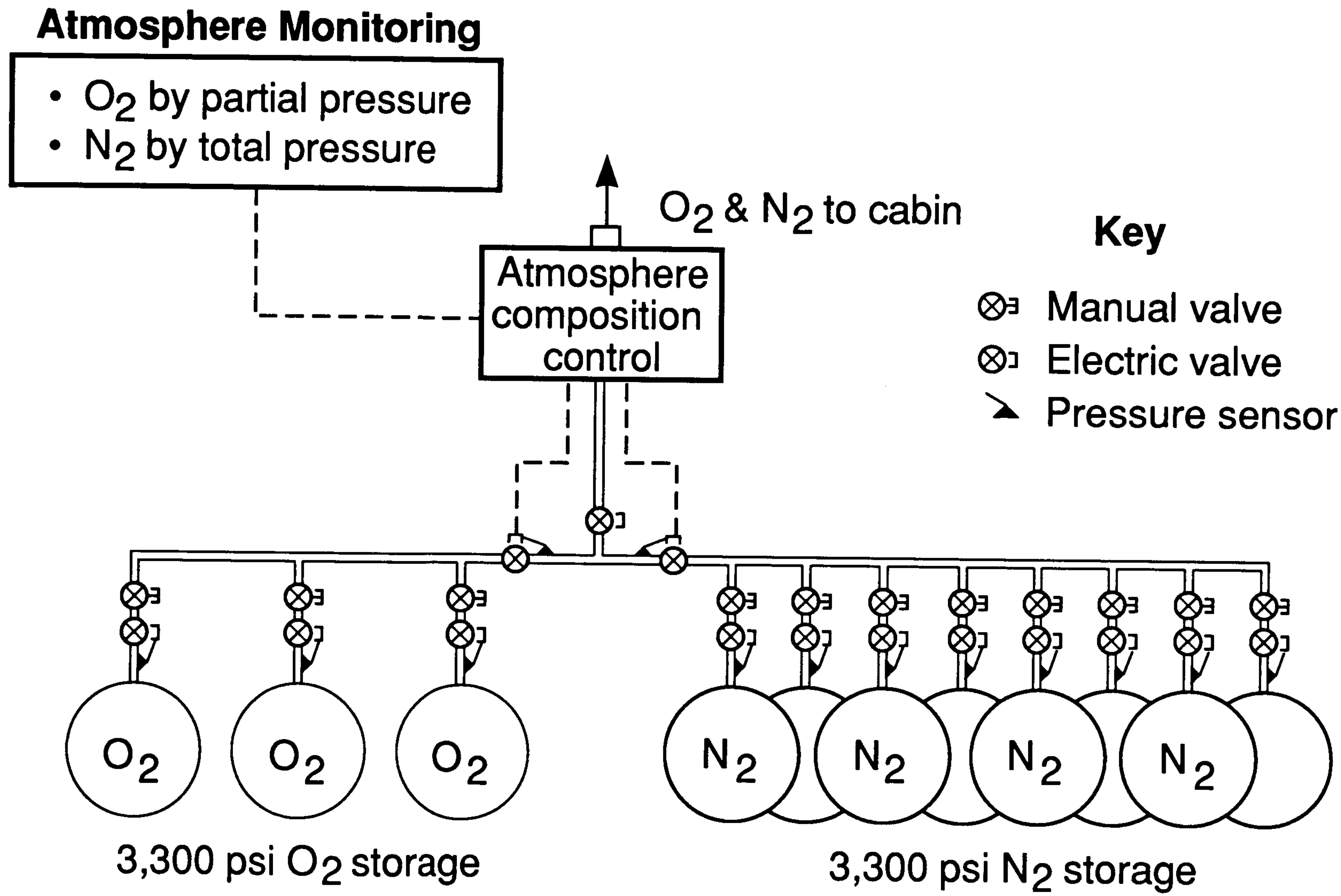
Ventilation
- Connects into shuttle's air revitalization system
- Includes ventilation ducting, outlet ducts, intake ducts, and cabin air fan
- Can be run in free flyer mode to remove contaminants

Fire detection and suppression
- Detection and pyro control subassemblies
- Fire extinguisher subassembly
- 1 portable fire extinguisher
- 3 emergency breathing packs

CONCEPT 2 ATMOSPHERE CONTROL AND SUPPLY SCHEMATIC

The atmosphere control and supply (ACS) system is designed to maintain the CDSF internal pressure at 14.7 PSIA with an O_2 partial pressure of 3.2 PSIA and an N_2 partial pressure of 11.5 PSIA. The oxygen and nitrogen are stored at 3,300 psi in shuttle type carbon wound filament tanks. The ACS contains sufficient gases to make up a CDSF leak rate of 0.5 lb/day for missions of 3 years and to repressurize the cabin once per shuttle visit. This system operates only in the free flyer mode. While the CDSF is docked with the shuttle, the shuttle will supply all makeup gases.

CDSF ATMOSPHERE CONTROL AND SUPPLY SCHEMATIC

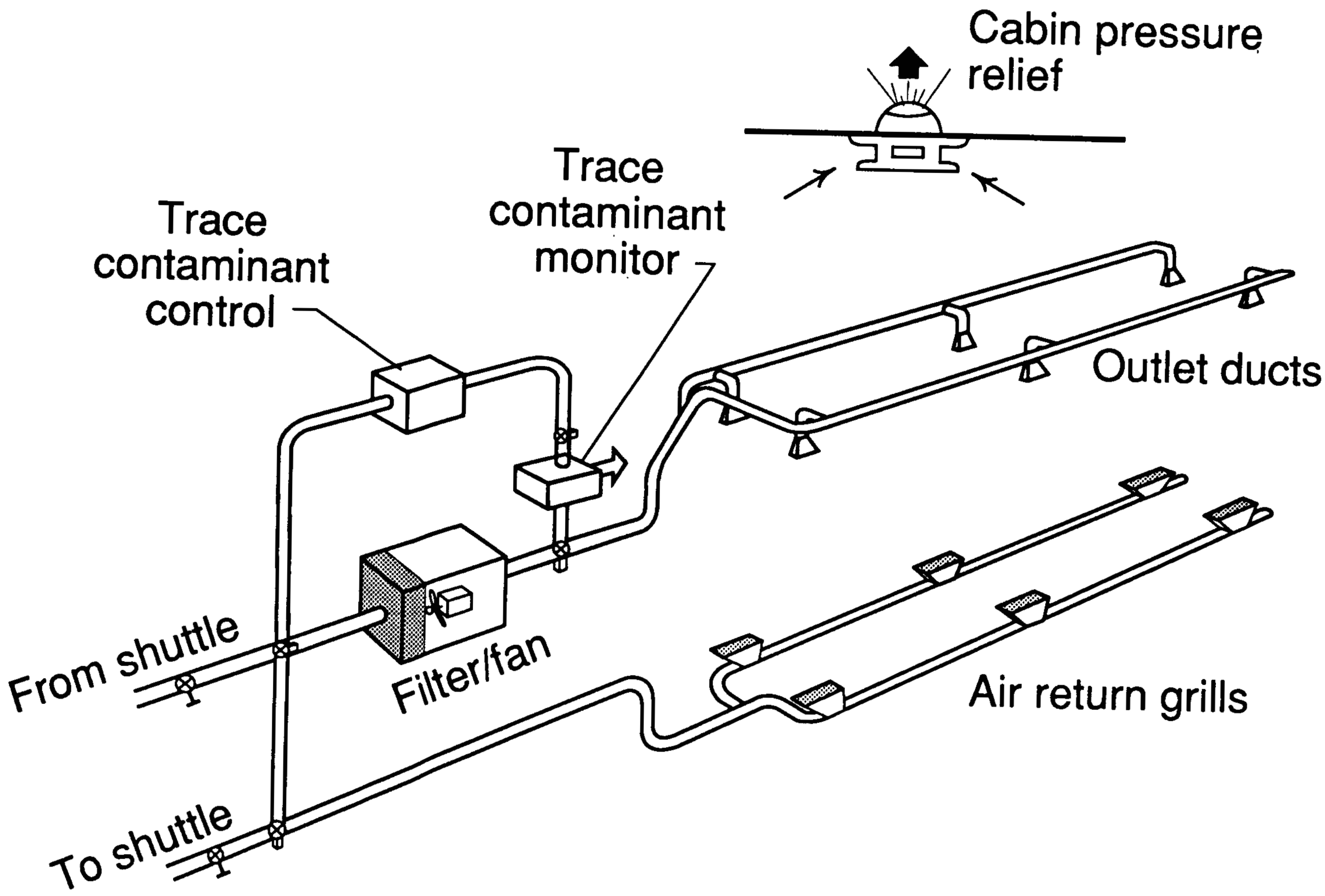


Note: 5 year mission requires an additional O_2 tank and 4 N_2 tanks resupply equals 180 days or 3 years

CDSF VENTILATION AND TRACE CONTAMINANT SCHEMATIC

The CDSF contains the interfaces required to connect to the shuttle's air revitalization system during mated operations. While the CDSF is docked to the shuttle, the shuttle's environmental control and life support systems remove carbon dioxide, humidity, and sensible heat. The shuttle also supplies metabolic oxygen, cabin air leakage makeup and airlock gas makeup. In the free flyer mode, the fan shown in the schematic diagram can be run so that trace contaminants can be monitored and removed by catalytic oxidation and filters.

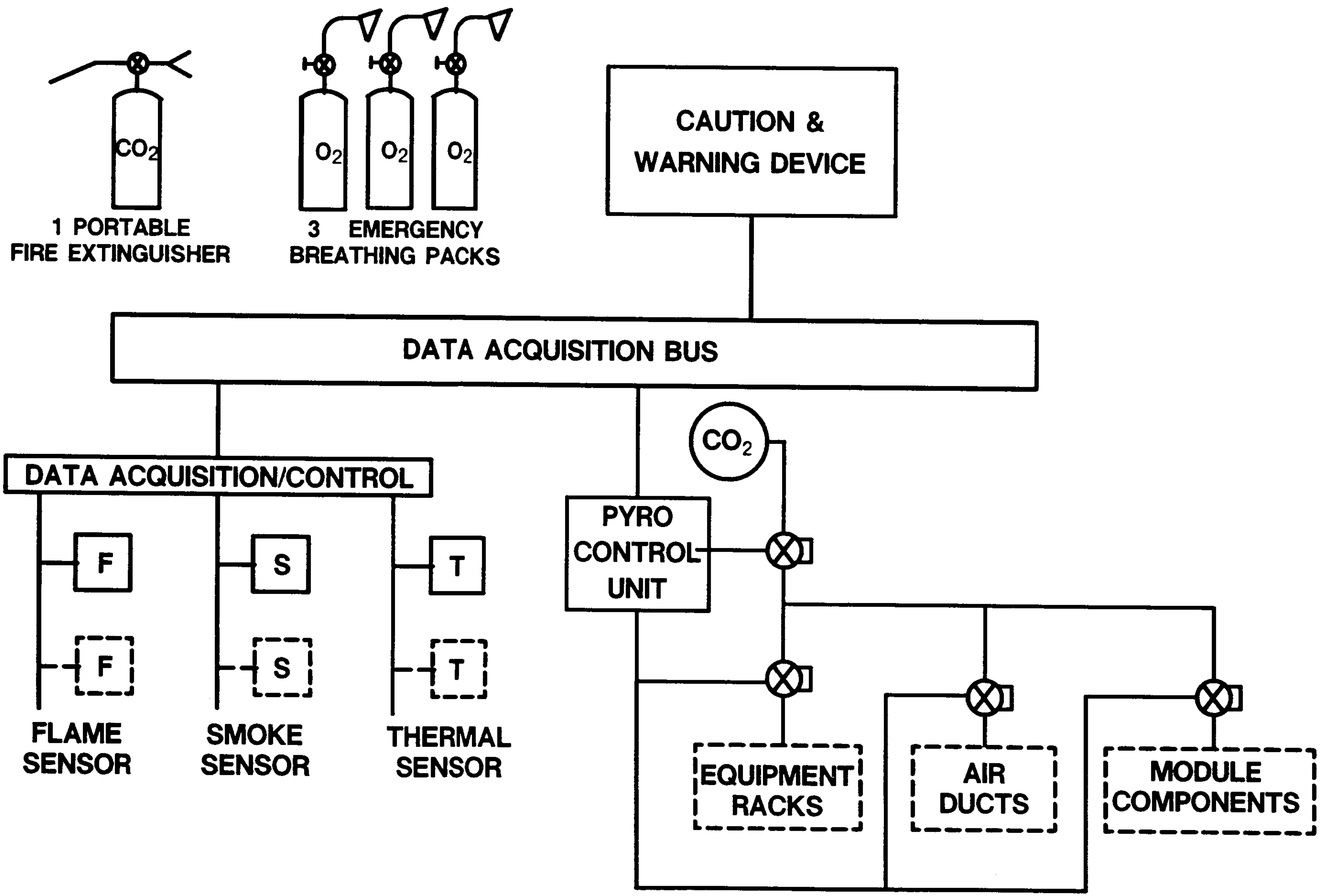
CDSF VENTILATION AND TRACE CONTAMINANT SCHEMATIC



CDSF FIRE DETECTION AND SUPPRESSION SYSTEM

The fire detection system contains sensors that identify flames, smoke or heat in the equipment racks, air ducts, and module components. The signals from the sensors automatically activate the suppression unit which applies CO_2 to control the fire. A portable fire extinguisher is included as well as 3 emergency breathing packs for crew safety.

CDSF FIRE DETECTION AND SUPPRESSION SYSTEM



CDSF FIRE DETECTION & SUPPRESSION SYSTEM WEIGHT BREAKDOWN

A weight breakdown for the fire detection and suppression system is presented.

CDSF FIRE DETECTION & SUPPRESSION WET WEIGHT

	WET WEIGHT (LBS)	
DETECTION		
Fire Detection Subassembly	31.4	
Pyro Control Box Subassembly	6.8	
SUPPRESSION		
Fire Extinguisher Subassembly	34.5	[25 LBS CO_2]
Portable Fire Extinguisher	6.9	[5 LBS CO_2]
3 Emergency Breathing Packs	3(17.6)	[3(1) LBS O_2]
Plumbing	16.0	
Valves	15.0	
Controller Assembly	10.0	
SUBTOTAL	173.4	[30 LBS CO_2] [3 LBS O_2]
CONTINGENCY (15%)	26.0	
TOTAL	199.4	

DRY WEIGHT = 173.4 - 33.0 = 140.4 LBS

CDSF ENVIRONMENTAL CONTROL SYSTEM SUMMARY

Weight, volume, power, and resupply were estimated for the CDSF systems with an internal pressurized volume of 1800 ft^3. The baseline definition is for a three year operational lifetime without resupply. Weights and volumes for a three year and five year system design are shown for comparison.

The main difference in the atmosphere supply system for the 3 year mission and the 5 year mission is the weight and volume required to store 2 extra years of cabin leakage makeup gases.

Resupply weights and volumes were also calculated for STS revisit missions of 6 months, 3 years and 5 years to perform resupply interval trade off analysis.

CDSF ENVIRONMENTAL CONTROL SYSTEM SUMMARY

Item	Flight Unit Wet Weight (lb)	Flight Unit Dry Weight (lb)	Flight Unit Volume (ft^3)	Resupply						Power (kW)
				180 Days		3 Years		5 Years		
				Weight (lb)	Volume (ft^3)	Weight (lb)	Volume (ft^3)	Weight (lb)	Volume (ft^3)	
Atmosphere supply	1424 * (2115) **	742 * (1067) **	52.8 * (76.7) **	445	17.2	1287	47.3	1928	68.8	0
Atmosphere Control & Monitoring	60	60	3.5	4	0.1	12	0.3	18	0.5	0.050
Trace Contaminant Control & Monitoring	214	214	6.5	11	0.3	64	1.9	107	3.0	0.330
Fire Detection & Suppression	173	140	3.3	4	0.1	23	0.4	38	0.6	0.109
Ventilation	81	81	15.6	0	0	5	0.5	5	0.5	0.053
Total	1952* (2643) **	1237* (1562) **	81.7 * (105.6) **	464	17.7	1391	50.4	2096	73.4	0.542

* Initial Flight Unit weight and volume for 3 year mission
** Initial Flight Unit weight and volume for 5 year mission

CDSF ENVIRONMENTAL CONTROL SYSTEM WEIGHT BREAKDOWN

A weight breakdown for the environmental control system is presented. Note that the heaviest part of the system is the atmosphere supply. The large weight is driven by the combination of two factors. The first is an assumed leakage rate of .5 pounds of air a day. The second factor is the requirement to maintain nominal atmospheric pressure for three years without orbiter resupply. Reduction of either one of these factors could significantly reduce the weight of the environmental control system.

CDSF ENVIRONMENTAL CONTROL SYSTEM

	WET	DRY
ATMOSPHERE SUPPLY	1424	742
ATMOSPHERE CONTROL & MONITORING	60	60
TRACE CONTAMINANT CONTL & MONITORING	214	214
FIRE DETECTION & SUPPRESSION	173	140
VENTILATION	81	81
SUBTOTAL	1952	1277
CONTINGENCY (15%)	293	186
TOTAL	2245	1423

NASA

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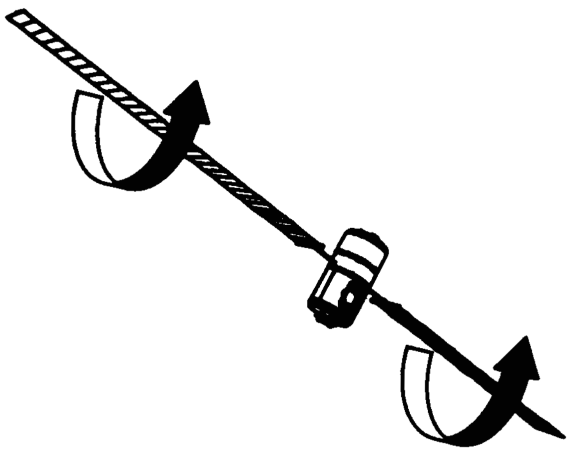
6.1.2.2. ELECTRICAL POWER SYSTEM

SOLAR ARRAY POWER GENERATION OPTIONS

Solar array power generation was investigated for both sun tracking arrays and feathered arrays. The sun tracking array option requires both alpha and beta articulation of the inertially sun pointed array with respect to the Earth oriented CDSF body axis. The feathered array option provides lower power for a given array size but minimizes aerodynamic drag and articulation requirements. This is the concept chosen for the CDSF configuration definition.

SOLAR ARRAY POWER GENERATION OPTIONS

SUN TRACKING ARRAYS



ARRAYS INERTIALLY POINTED TO SUN, ROTATING WITH RESPECT TO THE SPACECRAFT.

FEATHERED ARRAYS VBAR (-X)

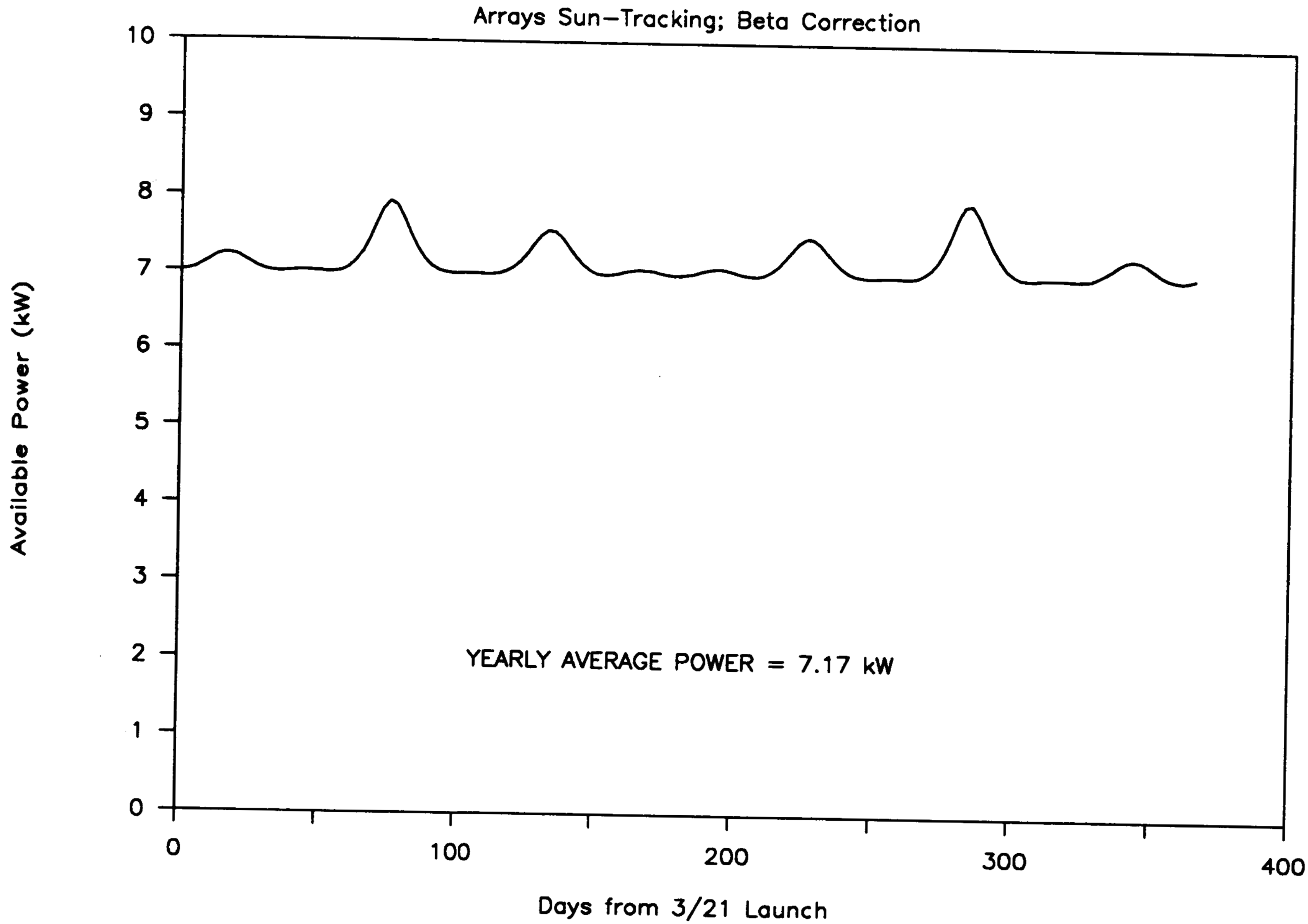
ARRAYS ORIENTED WITH THEIR NORMAL PERPENDICULAR TO V.

ARTFEAFF

SUN TRACKING POWER GENERATION OPTION

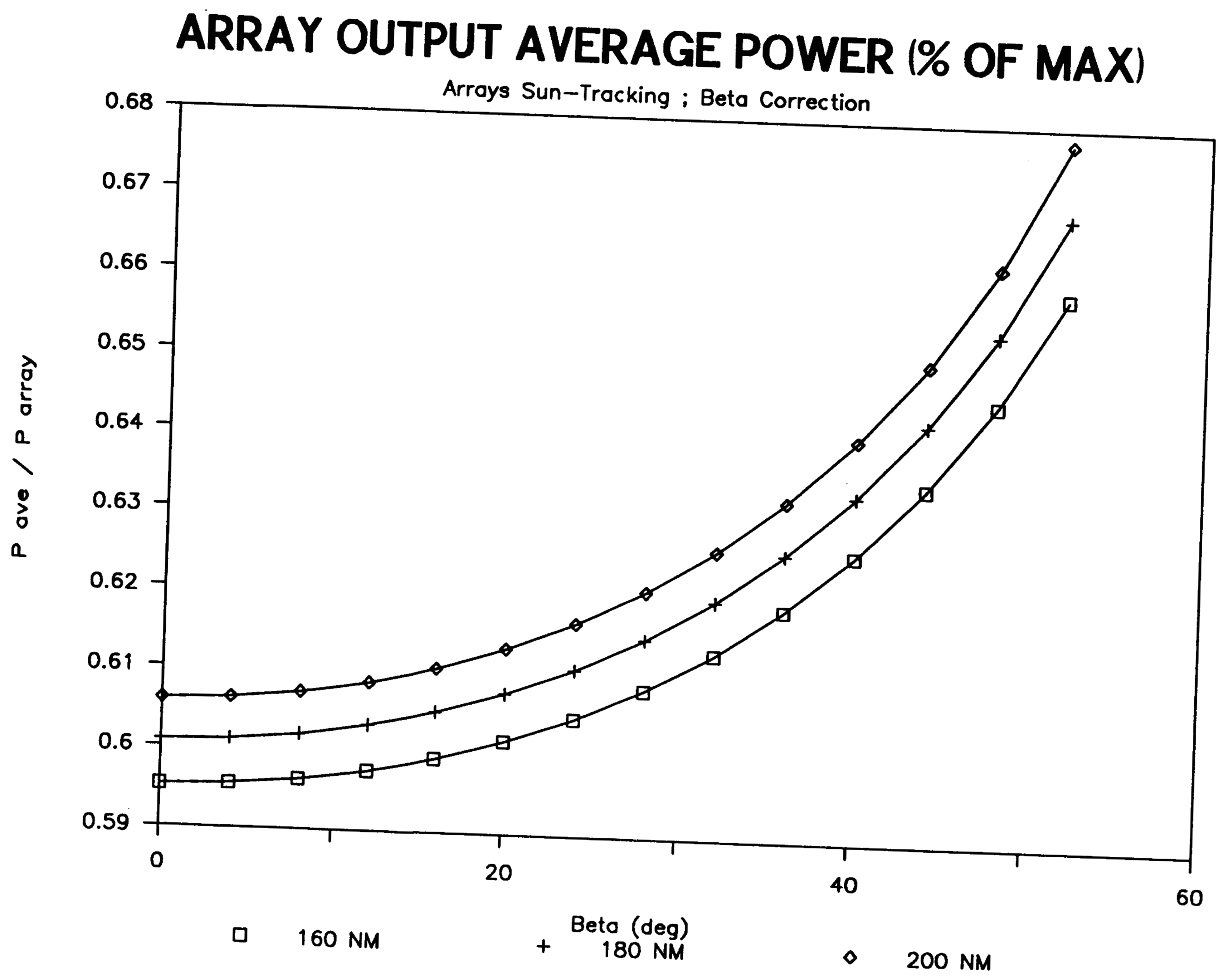
A solar array area of 1610 square feet provides a yearly average available power of 7.17 kW when continuously sun tracking in Earth orbit. Available power varies with time due to the seasonal change in solar beta angle which changes the time period during the orbit in which the Earth blocks the sun from the spacecraft (spacecraft orbital eclipse).

SUN TRACKING POWER GENERAT ARRAY SIZING



SUN TRACKING ARRAY OUTPUT AVERAGE POWER

Sun tracking arrays in low Earth orbit output on the average between 60 to 70 percent of their power generation capacity when they are inertially tracking the sun. Output power increases as the spacecraft orbital eclipse time period is reduced with increasing solar beta angle or with increasing orbital altitude.



ARRAY OUTPUT AVERAGE POWER (% OF MAX)
Arrays Sun–Tracking ; Beta Correction
P ave / P array
0.68
0.67
0.66
0.65
0.64
0.63
0.62
0.61
0.6
0.59
0
20
40
60
Beta (deg)
160 NM
180 NM
200 NM

CDSF POWER SYSTEM (ARRAYS SUN TRACKING)

The sun tracking array option reduces the required array area size by 50 percent over the feathered array option. Power output is relatively insensitive to solar beta geometry or to the altitudes investigated. Array average output power at a maximum solar beta angle increases by 10 percent over the average output power at a minimum solar beta angle. Array output average power increases by 1 percent for a +20 Nmi change in altitude. Although the required array area is reduced for the sun tracking option, the articulating arrays generate a large aerodynamic drag which has an adverse impact on the microgravity environment.

CDSF POWER SYSTEM (ARRAYS SUN-TRACKING)

- **SUN-TRACKING ARRAYS REDUCE REQUIRED ARRAY AREA SIZE BY FACTOR OF 2 OVER FEATHERED ARRAYS**

- **POWER RELATIVELY INSENSITIVE TO SOLAR BETA CHANGE**
  - Array output average power increases by factor of 1.1 for beta = 52 deg

- **POWER RELATIVELY INSENSITIVE TO ALTITUDE CHANGE**
  - Array output average power increases by 1% for +20 Nmi altitude change

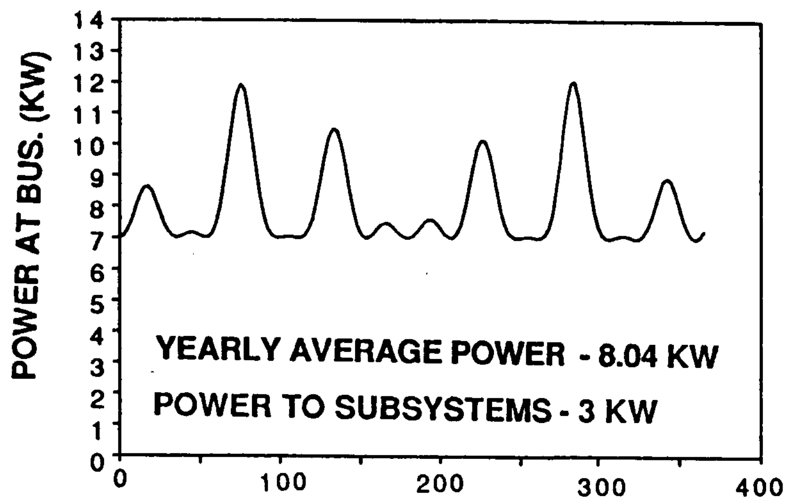
- **LARGE DRAG AREA INDUCES UNACCEPTABLE MICRO-G ENVIRONMENT**

FEATHERED ARRAY OPTIONS

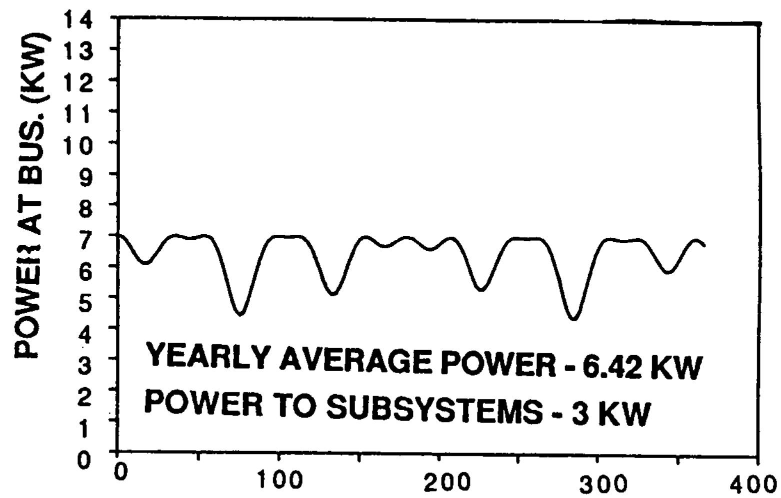
A solar array area of 3220 square feet provides a yearly average available power of 8.04 kW with beta adjustment and 6.42 kW with no beta adjustment. Available power varies with time due to the seasonal change in solar beta angle which changes the eclipse time period. Adjusting for the changing solar beta angle provides 1.6 kW more average available power. Significant peak power generation opportunities are available four times per year.

FEATHERED ARRAY OPTIONS

BETA ADJUSTMENT
AVAILABLE POWER (7 KW BUS. 3220 SQ FT ARRAY)



NO BETA ADJUSTMENT
AVAILABLE POWER (7 KW BUS. 3220 SQ FT ARRAY)

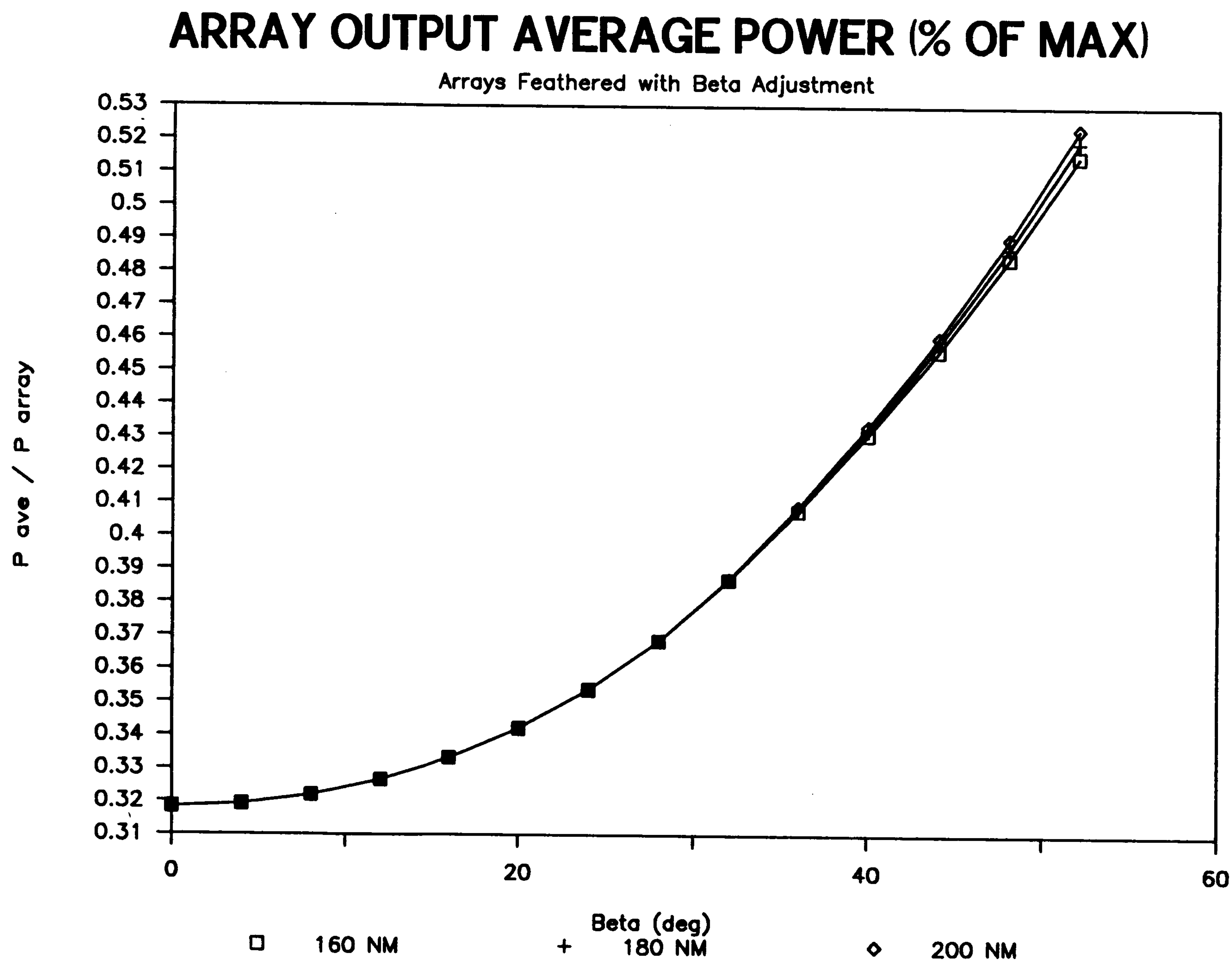


BETA ADJUSTMENT ADVANTAGES

- 2 KW MORE AVERAGE POWER AVAILABLE
- SIGNIFICANT PEAK POWER AVAILABLE 4 TIMES A YEAR FOR HIGH POWER USER SCENARIOS

FEATHERED ARRAY OUTPUT AVERAGE POWER

Feathered arrays in low Earth orbit output on average between 30 to 50 percent of their power generation capability when the arrays are adjusted to track the solar beta angle variation. Output power increases as the Earth orbit spacecraft eclipse time period is reduced with increasing solar beta angle. Output power is relatively insensitive to altitude changes of 20 Nmi.


ARRAY OUTPUT AVERAGE POWER (% OF MAX)
Arrays Feathered with Beta Adjustment
P ave / P array
0.53
0.52
0.51
0.5
0.49
0.48
0.47
0.46
0.45
0.44
0.43
0.42
0.41
0.4
0.39
0.38
0.37
0.36
0.35
0.34
0.33
0.32
0.31
0
20
40
60
Beta (deg)
160 NM
180 NM
200 NM

CDSF POWER SYSTEM (ARRAYS FEATHERED)

The feathered array with beta adjustment capability accommodates high power payload operation during high solar beta geometry orbits. Array average output power at maximum solar beta angle increases by a factor of 1.6 over output average power at minimum solar beta angle. Array average output power increases by a factor greater than 1.4 four times per year. This occurs twice a year for a 15 day interval and twice a year for a 10 day interval for a total of 50 days per year. Array pointing must be periodically adjusted for changing solar beta angle geometry at an average rate of 1.6 deg per day and peak rate of 3 deg per day. Array output power is relatively insensitive to changes in altitude of 20 Nmi.

CDSF POWER SYSTEM (ARRAYS FEATHERED)

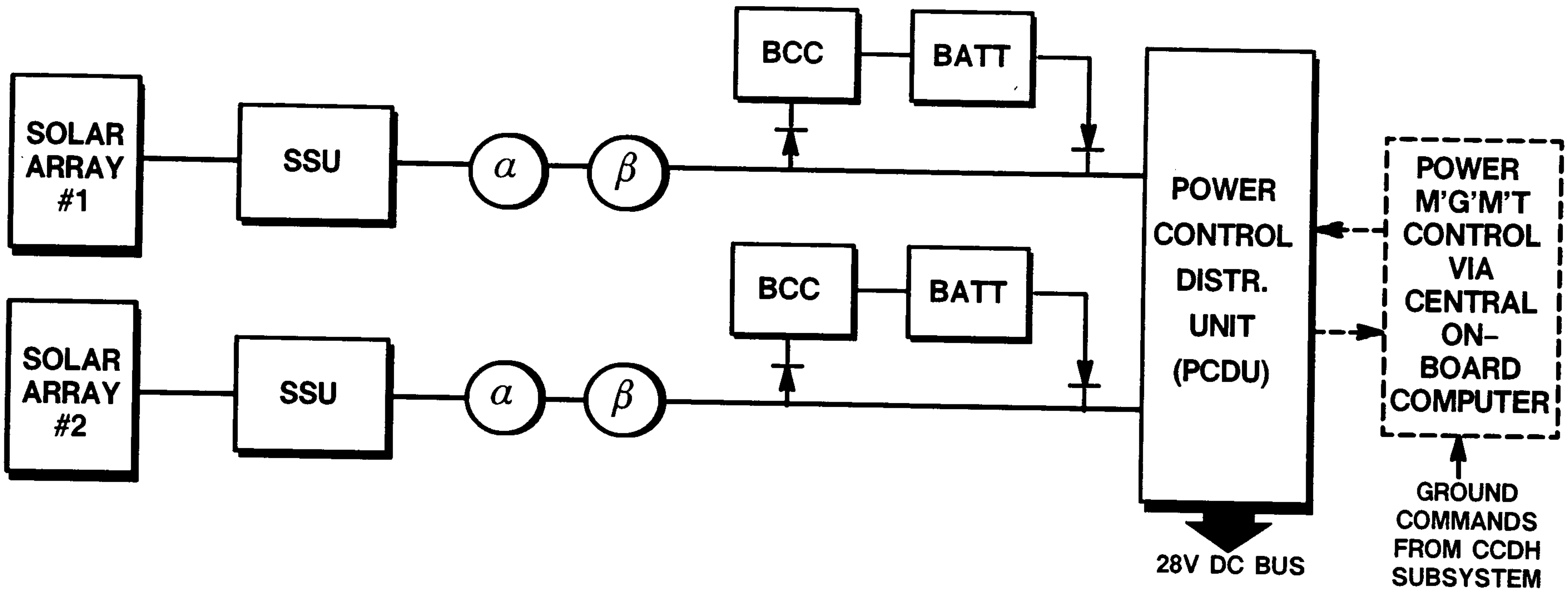
- **HIGH POWER PAYLOAD OPERATION SHOULD BE SCHEDULED DURING HIGH SOLAR BETA ORBIT**
  - Array output average power increases by factor of 1.6 for beta = 52 deg
1.4 for beta = 40 deg
  - Beta > 40 deg occurs 50 days (2 x 15 days, 2 x 10 days) per year
- **ARRAY POINTING MUST BE PERIODICALLY ADJUSTED FOR CHANGING SOLAR BETA ANGLE**
  - Requires articulation about velocity vector (1.6 deg per day average, 3 deg per day peak)
- **POWER INSENSITIVE TO ALTITUDE CHANGE OF ±20 Nmi**

CDSF POWER SYSTEM SIZING TRADE SUMMARY

A weight breakdown for two sun tracking and two feathered array size options was generated to determine and assess the weight penalty associated with using a feathered array concept for the CDSF power system definition. For the final concept definition the weight penalty for the feathered arrays was accepted to achieve a more favorable acceleration environment to accommodate microgravity experiments.

A power system schematic illustrates that each option has two solar arrays connected to single dual redundant Power Control Distribution Unit (PCDU). Also, power management and control is performed via a central on-board computer that is part of the Command, Control and Data Handling System (CCDH). Battery charge controllers (BCC) are shown for each Battery (BATT) unit. Solar Array Shunt Units (SSUs) are located on each solar array blanket.

CDSF POWER SYSTEM SIZING TRADE SUMMARY



	AVERAGE POWER / WORST CASE BETA SIZING / 3KW HOUSEKEEPING			
	10 KW SUN TRACKING	10 KW FEATHERED	7 KW SUN TRACKING	7 KW FEATHERED
CABLING	TBD	TBD	TBD	TBD
SOLAR ARRAYS (2) - SA	1100#(2300 ft^2)	2200#(4600 ft^2)	770 #(1610 ft^2)	1540#(3220 ft^2)
SOLAR ARRAY BOOMS (2) - SAB	400	400	400	400
SOLAR ARRAY SHUT UNITS (2) - SSU	40	80	30	60
ALPHA JOINTS (2) - α	250	-	175	-
BETA JOINTS (2) - β	100	150	75	100
BATTERY CHARGE CONTROL (2) - BCC	160	240	110	165
BATTERIES (2 SETS) - BATT	1460	2190	1020	1530
POWER CONTROL DISTRIBUTION UNIT - PCDU	150	150	150	150
TOTAL WEIGHT (Lbs)	3660	5410	2730	3945

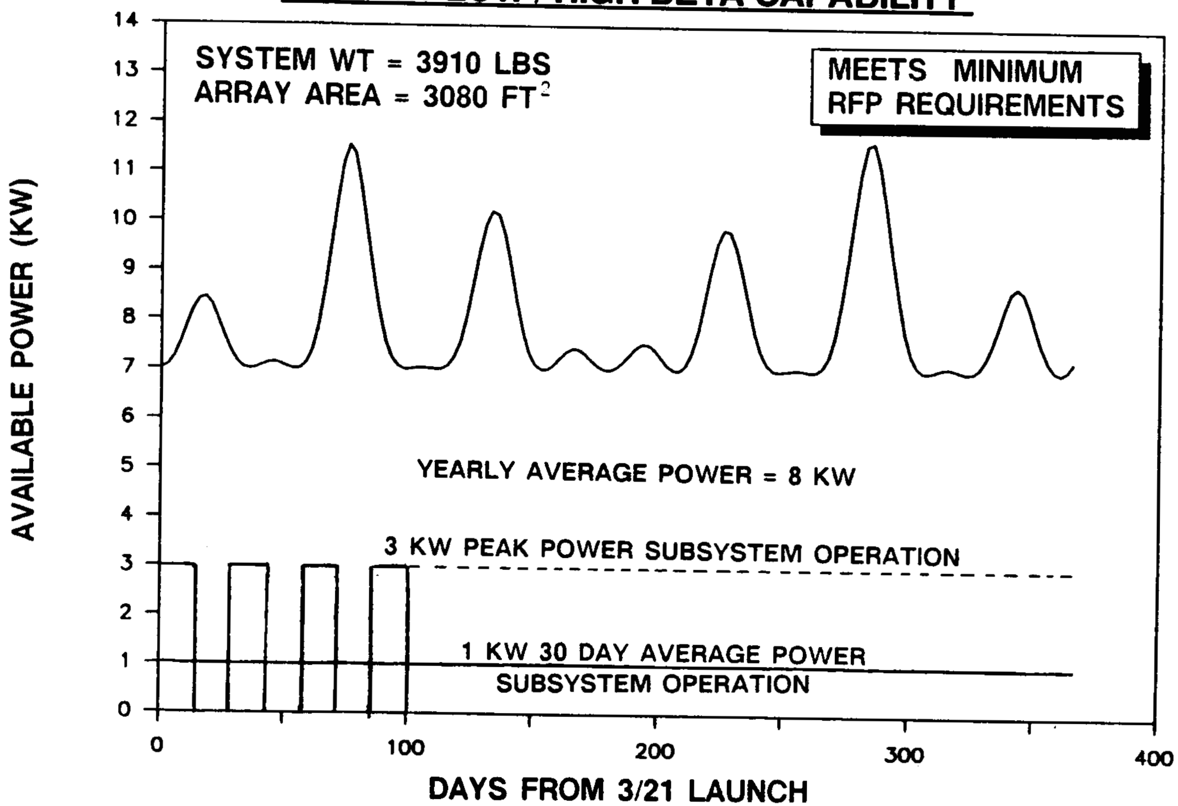
CDSF POWER SYSTEM SIZING

A solar array area of 3080 square feet provides a yearly average available power of 8 kW when operated in a feather orientation with beta adjustment. Available power varies from 7 kW to 12 kW with power greater than 10 kW four times (50 days total) per year. With a 33 percent subsystem operation duty cycle (1 kW average) assumed , power availability to the experiments meets the minimum RFP average user power requirements of 7 kW.

100% CDSF CONCEPT POWER SYSTEM SIZING

- FEATHERED SOLAR ARRAY CONFIGURATION WITH BETA TRACKING CAPABILITY MEETS REQUIREMENT FOR 1 MICRO G FOR 30 DAY OPERATION FOR 174 NMI STS RENDEZVOUS ALTITUDE
- 7 / 12 KW LOW / HIGH BETA CAPABILITY CONFIGURATION MEETS MINIMUM AVERAGE POWER NEEDS
  - POWER AT BUS > 10 KW OCCURS 50 DAYS (2 X 15 DAYS, 2 X 10 DAYS) PER YEAR

7 / 12 KW LOW / HIGH BETA CAPABILITY



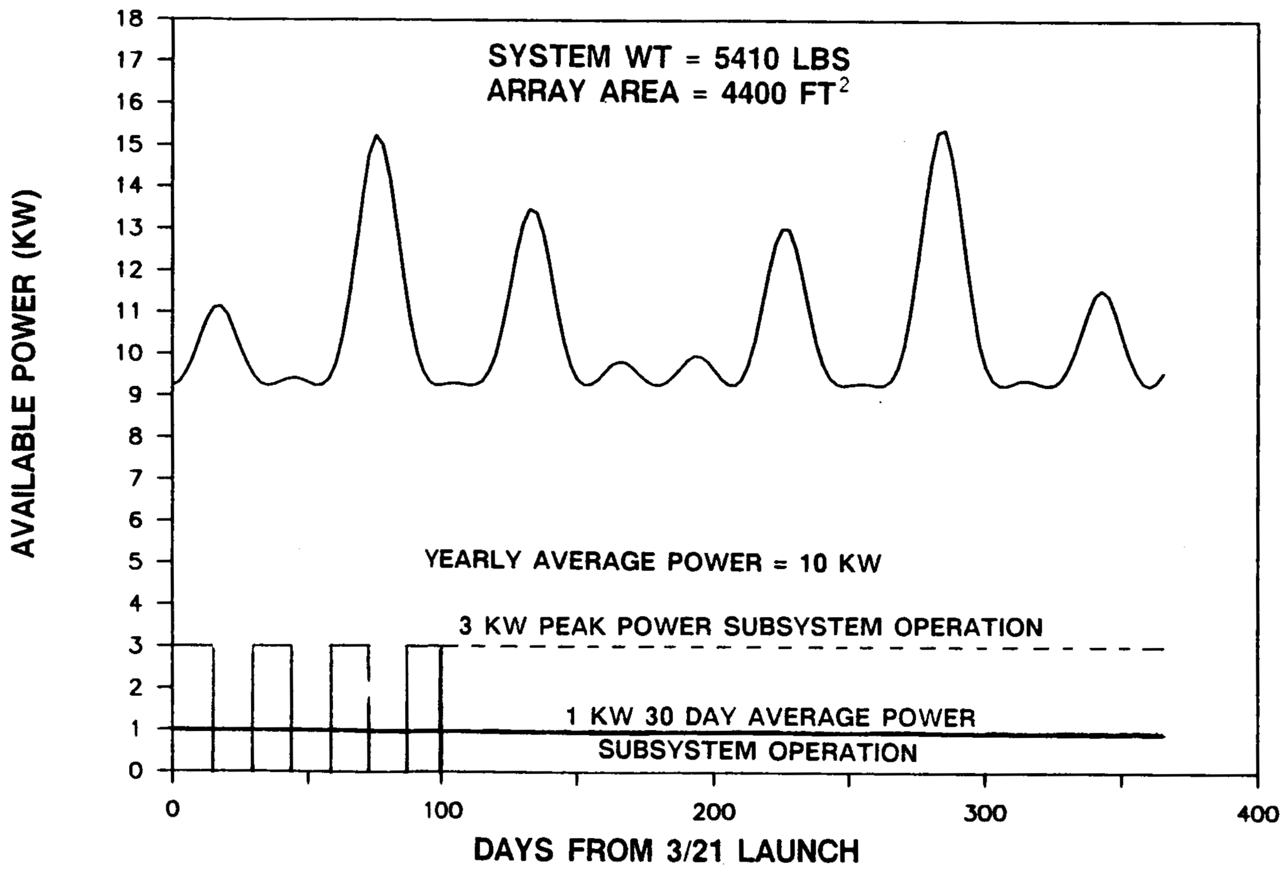
MN/C6

9.6 / 16 KW LOW / HIGH BETA CAPABILITY

For an additional 1500 lb, a solar array area of 4400 square feet provides a yearly average available power of 10 kW when operated in a feathered orientation with beta adjustment. Available power varies from 9.6 kW to 16 kW with power greater than 10 kW four times (100 days total) per year. With a 33 percent duty cycle assumed (1 kW average), power availability for experiment operation is at least 8 kW during periods of minimum solar array power generation capability.

9.6 / 16 KW LOW / HIGH BETA CAPABILITY

- 9.6 / 16 KW LOW / HIGH BETA CAPABILITY CONFIGURATION REQUIRES 1500 LBS EXTRA
  - YEARLY AVERAGE ALWAYS PROVIDES 7 KW USER POWER AT PEAK OPERATION
  - POWER AT BUS > 10 KW OCCURS 100 DAYS (2 X 30 DAYS, 2 X 20 DAYS) PER YEAR



MN/C7

POWER SYSTEM DESIGN

The power system hardware is defined to be based on existing technology and flight proven components. Batteries are initially charged and brought on-line using Flight Support Equipment (FSE) located in the Orbiter cargo bay. A modular design allows ease of replacement. The power system is controlled by the CDSF main computer. Users are provided with 28 VDC, 7 kW average power with at least 9 kW available for 2 weeks occurring four times per year for the configuration concept defined.

POWER SYSTEM DESIGN

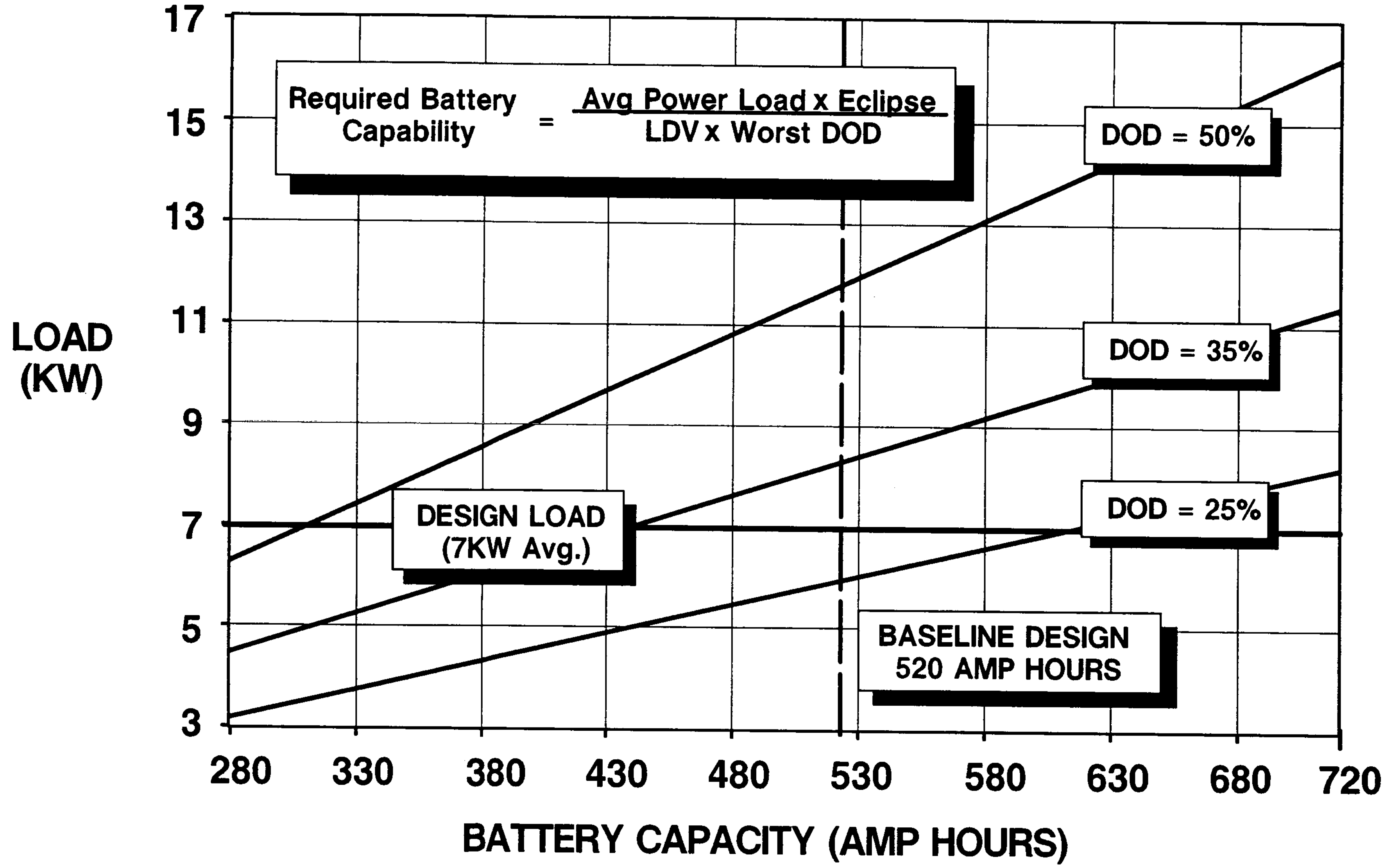
- HARDWARE BASED ON EXISTING TECHNOLOGY
- FLIGHT PROVEN DISTRIBUTION COMPONENTS
- FLIGHT PROVEN HIGH DENSITY NI–H2 BATTERIES
- BATTERIES INITIALLY CHARGED AND SYSTEMS BROUGHT ON–LINE FROM FLIGHT SUPPORT EQUIPMENT (FSE) LOCATED IN ORBITER BAY
- MODULAR DESIGN FOR EASE OF REPLACEMENT
- SYSTEM WILL BE CONTROLLED BY SPACECRAFT MAIN COMPUTER
- 28 VDC, 7 KW (AVG) WITH AT LEAST 9 KW FOR 2 WEEKS OCCURRING 4 TIMES/YEAR, AVAILABLE TO USERS

BATTERY SIZE ESTIMATION

The design concept defined for the CDSF Power Subsystem utilizes photovoltaic solar arrays for power generation and nickel hydrogen batteries for energy storage. The primary parameter for sizing the capacity of required energy storage is the orbit solar eclipse time that the CDSF spends in the Earth's shadow. The average energy load versus battery capacity plot shown here depicts three levels of depth of discharge (DOD) - 25%, 35% and 50%. A 30% DOD was defined for CDSF sizing which requires a 520 ampere hour battery storage capacity as indicated.

BATTERY SIZE ESTIMATION

LDV = 28 v, 37 MINUTE AVERAGE ECLIPSE

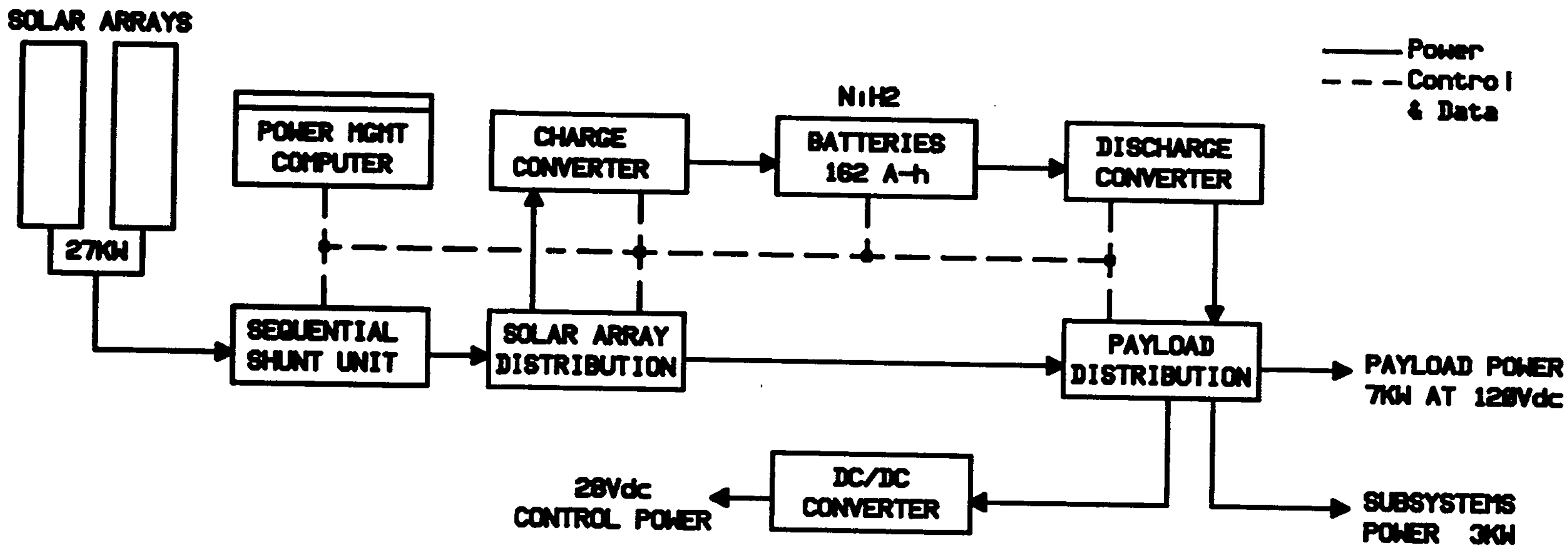


battery

CDSF CONCEPT #1 ELECTRICAL POWER SYSTEM (BLOCK DIAGRAM)

The block diagram illustrates the electrical power distribution system. The power output from the solar arrays is limited by the sequential shunt unit (SSU) which is controlled by the Power Management Computer (PMC). The solar power is divided to recharge batteries and provide payload and subsystems power during the sunlight portion of the orbit. During the eclipse power is supplied to the power distribution system by the batteries.

CDSF CONCEPT #1 ELECTRICAL POWER SYSTEM
120 Vdc +/- 4Vcd DISTRIBUTION BUS (Redundant)

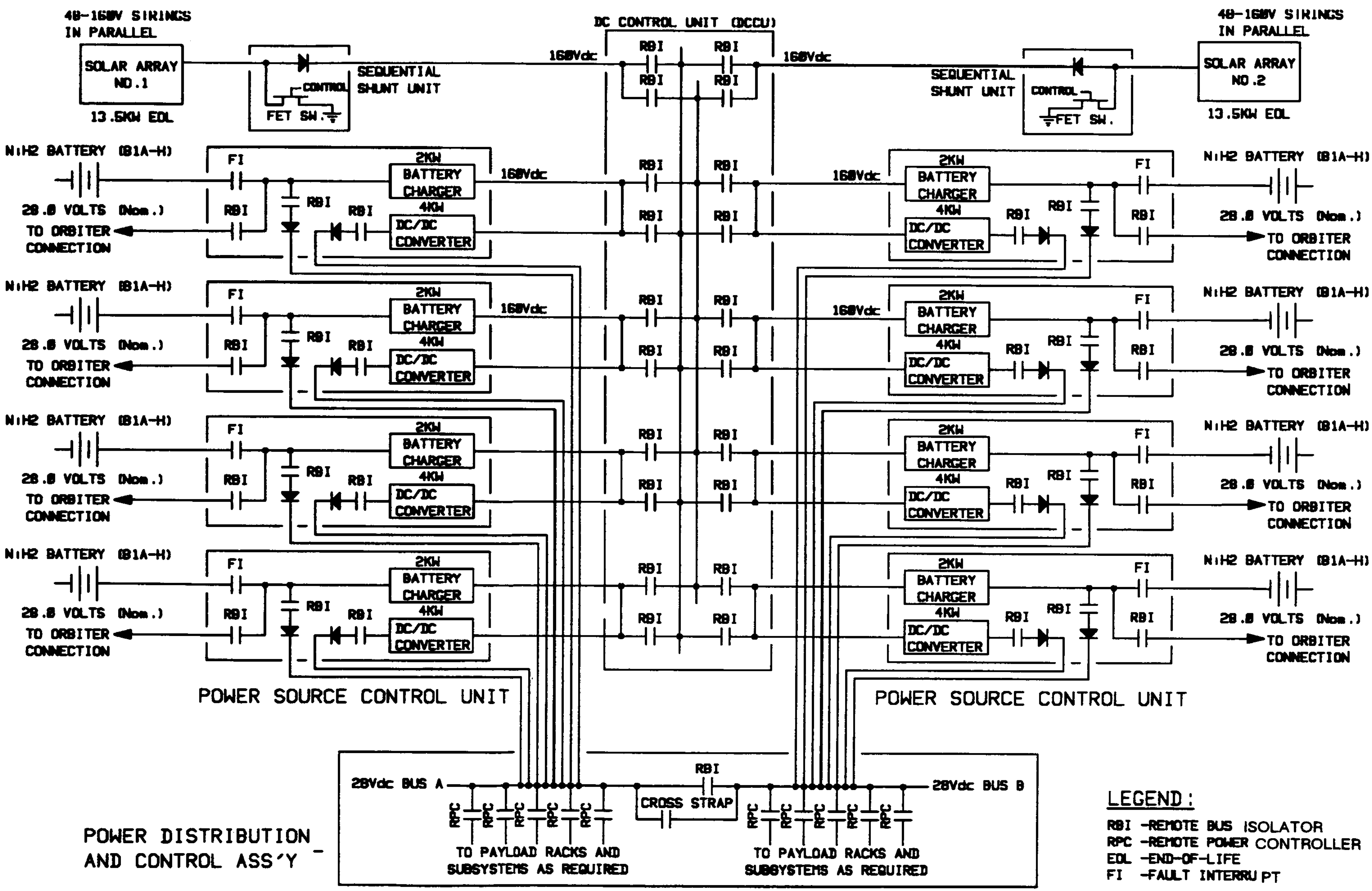


cdsf100eps

CDSF CONCEPT #1 POWER DISTRIBUTION SYSTEM

The schematic illustrates the redundancy of the power distribution system. The solar array, charge, discharge, and load currents, as well as the battery parameters, are monitored by the Power Management Computer which then controls the Sequential Shunt Unit, Battery Charge/Discharge Unit and various switching arrangements. Each system battery is composed of three (3) 81 ampere-hour Nickel-Hydrogen ORUs. The solar array output voltage selected for this study was 160 Vdc. The distribution voltage was 28 Vdc.

CDSF 28Vdc POWER DISTRIBUTION SYSTEM

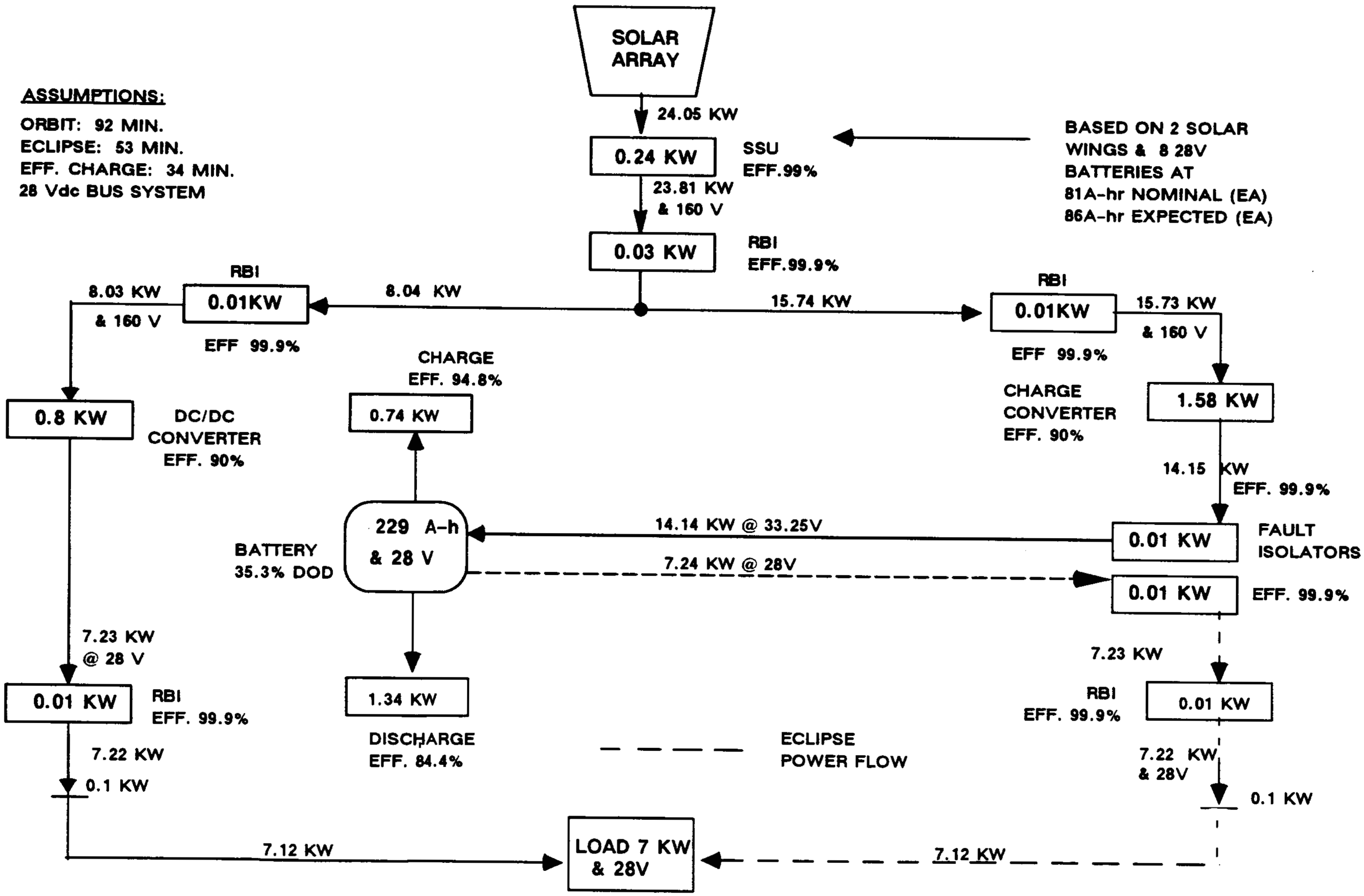


CDSF CONCEPT #1 POWER SYSTEM EFFICIENCIES

The diagram depicts the power losses in the 28-volt dc system with a 7 KW load. The calculations were also based upon a 92 minute orbit with a 53 minute eclipse and effective charge time of 34 of the 39 sunlight minutes. The five (5) minutes difference is recommended for charge margin and thermal stabilization time. The average power output from the solar array would have to be 24.05 KW to recharge the batteries and furnish 7 KW to the load. The batteries would discharge to a depth of 35.3%. The maximum DOD for NiH2 batteries can be 80%.

100% CDSF CONCEPT POWER SYSTEM EFFICIENCIES

7 KW AVERAGE POWER - 28 Vdc Bus System



mnc3

ELECTRICAL POWER SYSTEM WEIGHTS

The weight allocation is given for the CDSF Electrical Power System. Component weights are presented for a feathered solar array with beta adjustment configuration.

ELECTRICAL POWER SYSTEM WEIGHTS

SOLAR ARRAYS (2)	1309
SOLAR ARRAY BOOMS (2) (SAB)	340
SOLAR ARRAY SHUNT UNITS (2) (SSU)	51
BETA JOINTS (2)	85
SOLAR ARRAY DRIVE ELECTRONICS	43
BATTERY CHARGE CONTROL (2) (BCC)	140
BATTERIES (2 SETS)	1301
POWER CONTROL DISTRIBUTION UNIT (PDCU)	128
SUBTOTAL	3397
CONTINGENCY (15%)	510
TOTAL	3907

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6.1.2.3. THERMAL CONTROL SYSTEM

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CDSF THERMAL CONTROL DESIGN DESCRIPTION

The thermal control system is sized for an experiment load of 9.0 kw and a peak avionics load of 3.0 kw. Heat is acquired by a single-phase pumped water loop with redundant lines and pumps. Experiment hardware will provide cold plates if needed and rack connections will be available. Water will be pumped to a freon 21/water interchanger from which single phase freon 21 will be pumped to the radiators along redundant lines. The single phase freon 21 Space Shuttle technology radiators are sized for 12 kw continuous operation with an average environmental sink temperature of -60 degrees C.

CDSF THERMAL CONTROL DESIGN DESCRIPTION

Acquisition:

- Experiment heat load size for 9.0 kW
- Heat acquired by single-phase pumped water loop
- Avionics cooling provided by OMV
- Experimenters provide cold plates. Rack connections available.
- Subsystem includes redundant lines and pumps

Transport:

- Freon 21/water interchanger
- Pumped single phase freon 21
- Redundant lines and pumps

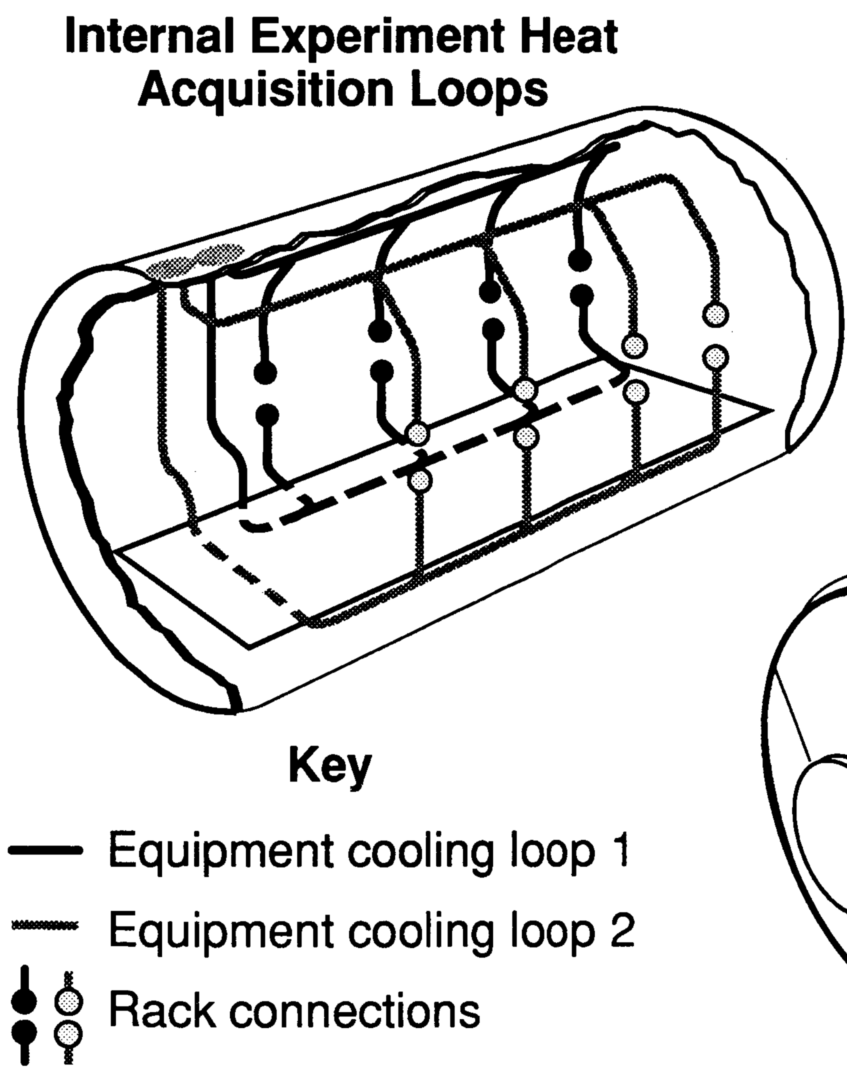
Rejection:

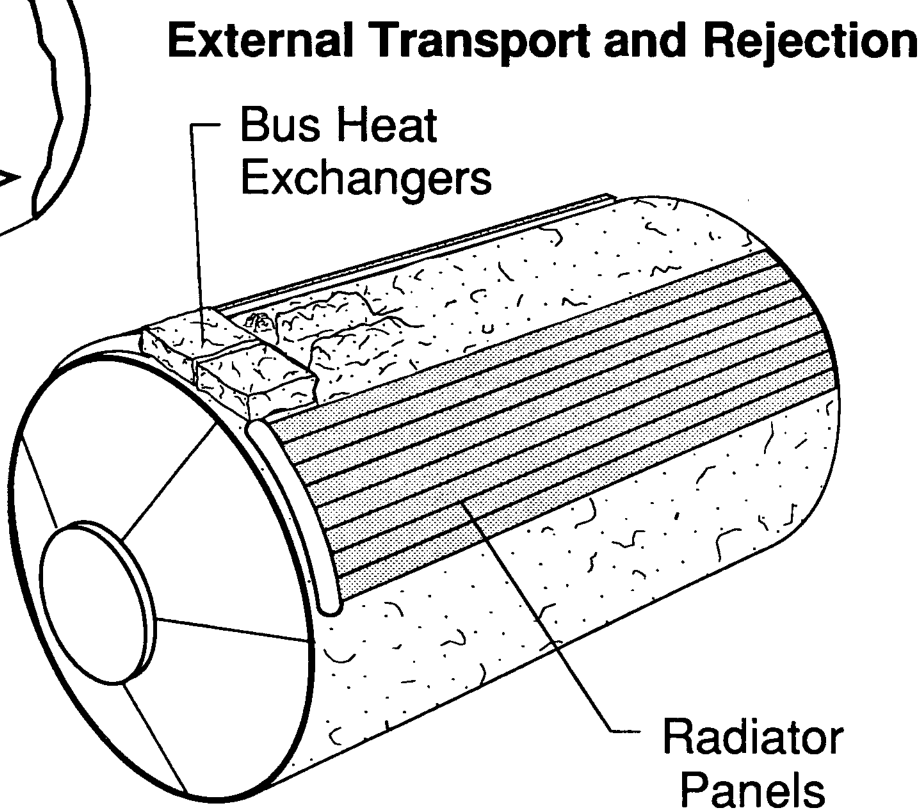
- Sized for 6 kW continuous operation
- Radiators sized for orbit with average environmental sink temperature of -60°C
- Single phase freon 21 radiators of Space Shuttle technology
  - Emissivity of 0.76
  - Solar absorptivity of 0.11
- Radiator micrometeroid protection provided

CDSF THERMAL CONTROL DESIGN DESCRIPTION

The CDSF thermal control technologies are shuttle and spacelab derived. The experiment rack heat loads are acquired by pumped single phase water loops operating between 40° to 100° F. Avionics are also cooled with cold plates using a single phase pumped water loop. Avionics and rack air cooling were not selected for primary operation in order for continued operation in case of reduced pressure. A single phase pump freon 21 loop picks up the internal heat loop with a freon / water interchanger. For heat rejection to space, the freon is pumped through a set of parallel tubes attached to a micrometeoroid shield. The entire shield acts as the radiating surface.

THERMAL CONTROL SYSTEM





EXPERIMENT RACK THERMAL SIZING

The primary system for experiment rack thermal control consists of dual thermal loops sized for 18,000 BTU/hour capacity each. Each thermal loop accommodates four experiment racks. The primary system for the racks is single phase water loop to cold plate heat transfer. However, existing air-cooled experiment hardware can be accommodated during nominal cabin air pressure operating conditions. The combined total capacity of both fluid loops can accommodate a peak experiment operational load of 10 kW.

Peak power generation operating capacity for three rack locations can accommodate 7 kW peak power operation for 30 minutes during low solar beta conditions. Twelve kilowatt peak operation for 18 minutes can be accommodated during periods of high solar beta conditions

EXPERIMENT RACK THERMAL SIZING

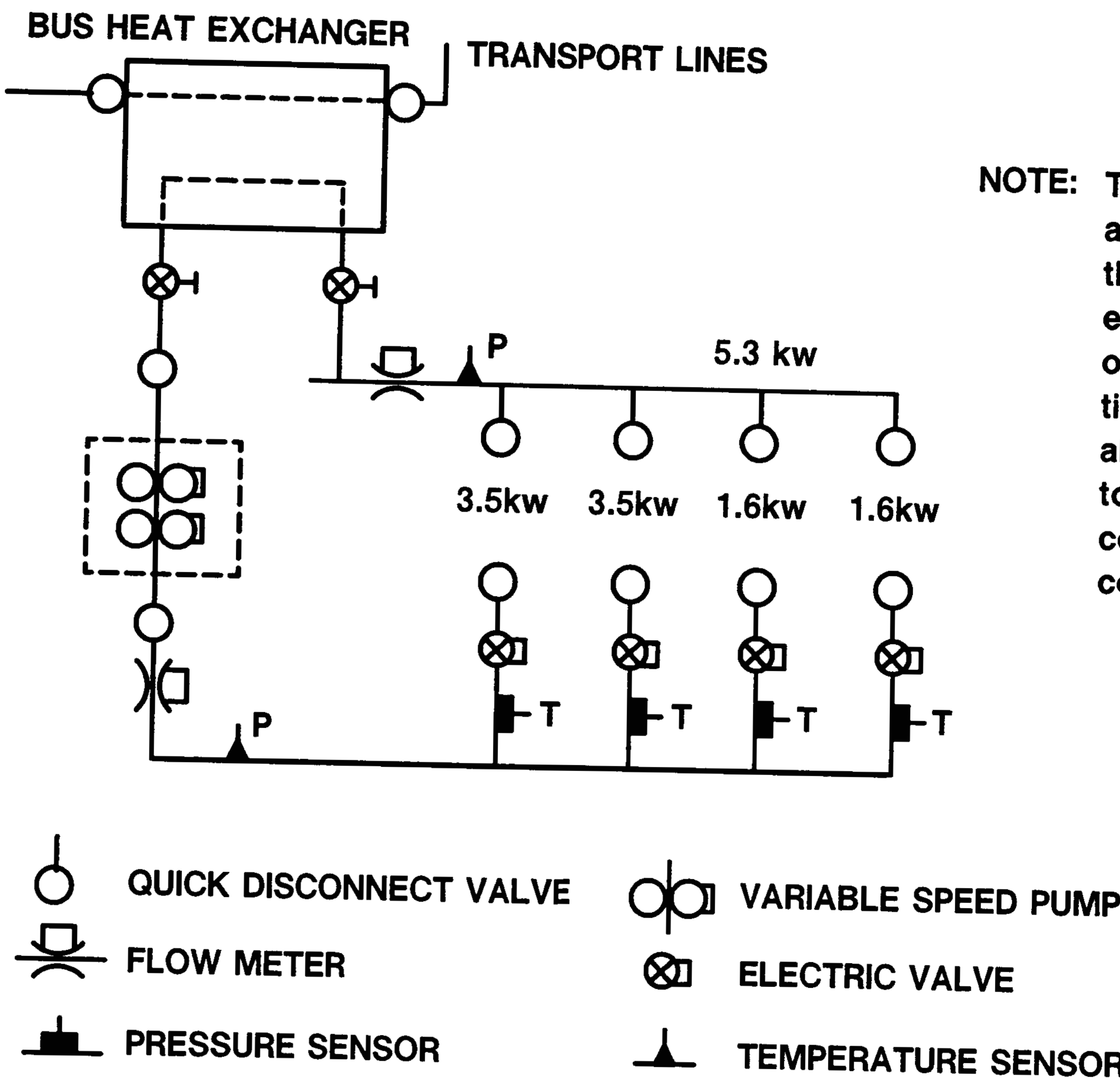
- PRIMARY SYSTEM IS SINGLE PHASE WATER TO COLD PLATES
- DUAL THERMAL LOOPS SIZED AT 18,000 BTU / HR (5.3 KW) FOR MINIMUM WEIGHT
  - -- 4 EXPERIMENT RACKS PER LOOP
  - -- PROVIDE 10 KW AVERAGE POWER DURING HIGH BETA POWER GENERATION CONDITIONS
- RFP REQUIRES 3 RACK LOCATIONS TO BE TIME SEQUENCED FOR PEAK POWER GENERATION CONDITIONS
  - -- EACH LOOP CONTAINS TWO 12,000 BTU/HR (3.5 KW) RACK LOCATIONS AND TWO 6,000 BTU/HR (1.6 KW) RACK LOCATIONS
  - -- ANY TWO RACKS ON SEPARATE LOOPS MAY BE TIME SEQUENCED FOR HIGH / LOW BETA PEAK POWER CONDITIONS, AS FOLLOWS:

BETA CONDITIONS	PEAK POWER	RUN TIME
LOW	7 KW	30 MIN
HIGH	12 KW	18 MIN

<u>CDSF LAYOUT OF INTERNAL HEAT ACQUISITION LOOPS</u>

This layout shows the internal heat acquisition loops which provide cooling to each rack location. For the CDSF, two such loops would be used with an average 5.3 kW capacity each to provide cooling at eight rack locations.

CDSF #1 THERMAL CONTROL SYSTEM: ACQUISITION



NOTE: There are two 5.3 KW capacity acquisition loops. Each of these loops provide 4.5 KW of experiment cooling and .8 KW of avionics cooling. an additional 1.4 KW avionics loop is also included which provides a total of 9.0 KW experiment cooling and 3.0 KW avionics cooling.

CDSF ACTIVE THERMAL CONTROL SYSTEM SUMMARY

This is a summary of the thermal control system weight, power, volume, and resupply estimates. The relatively light weight of the rejection system was accomplished by using the micrometeoroid shield as the radiator fin. This system can provide the CDSF with an orbital average of 12 kW heat rejection capability.

CDSF ACTIVE THERMAL CONTROL SYSTEM SUMMARY

Item	Flight Unit Wet Weight (lb)	Flight Unit Dry Weight (lb)	Flight Unit Volume (ft^3)	Resupply						Power (kW)
				180 Days		3 Years		5 Years		
				Weight (lb)	Volume (ft^3)	Weight (lb)	Volume (ft^3)	Weight (lb)	Volume (ft^3)	
Experiment Acquisition (4.5 kW)	230	218	2.9	5	0.1	27	0.3	46	0.6	0.10
Experiment Acquisition (4.5 kW)	230	218	2.9	5	0.1	27	0.3	46	0.6	0.10
Avionics Acquisition (3 kW)	160	155	2.7	3	0.1	19	0.3	32	0.5	0.02
Transport	550	371	48.0	6	1.1	18	3.3	37	6.6	0.95
Rejection	445	380	20.0	44	1.9	132	5.7	220	9.5	0
Total	1615	1343	76.5	63	3.3	223	9.9	381	17.8	1.17

CDSF THERMAL CONTROL SYSTEM WEIGHT BREAKDOWN

A weight breakdown for the thermal control system is presented. The rejection system uses the micrometeoroid shield as the radiator fin.

CDSF THERMAL CONTROL SYSTEM WEIGHTS

	WET	DRY
EXPERIMENT ACQUISITION (4.5KW)	230	218
EXPERIMENT ACQUISITION (4.5KW)	230	218
AVIONICS ACQUISITION (3KW)	160	155
TRANSPORT	550	371
REJECTION	455	380
SUBTOTAL	1615	1343
CONTINGENCY (15%)	242	201
TOTAL	1857	1544

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6.1.2.4. PROPULSION / REACTION CONTROL SYSTEM

REBOOST / REACTION CONTROL SYSTEM

The propellant for reboost and attitude control is heated water. Water is re-supplied from the Orbiter during revisit missions. Six resistojets provide three-axis attitude control and low thrust reboost. A reboost scenario with a 160 Nmi deployment altitude and a 202 Nmi rendezvous altitude was used for propellant sizing.

REBOOST / REACTION CONTROL SYSTEM

- HEATED H20 PROPELLANT SYSTEM RESUPPLIED WITH WATER TRANSFERRED FROM ORBITER

- RCS ATTITUDE CONTROL PERFORMED WITH 6 RESISTOJETS

- REBOOST WITH LOW THRUST CONTINUOUS BURN

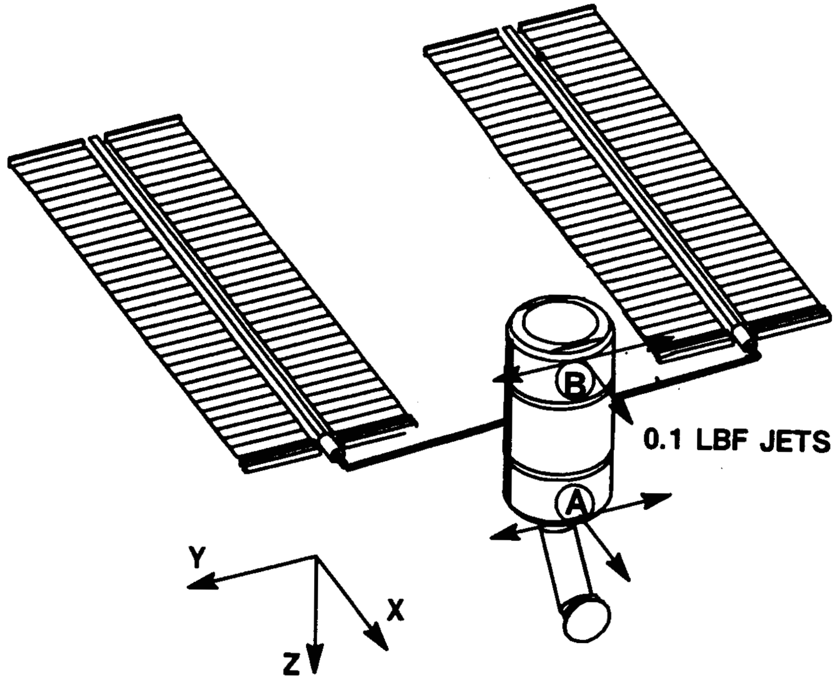
- 160 Nmi DEPLOYMENT ALTITUDE

- 202 Nmi RENDEZVOUS ALTITUDE
  - ALLOWS 1 MICRO-G EXPERIMENT ENVIRONMENT

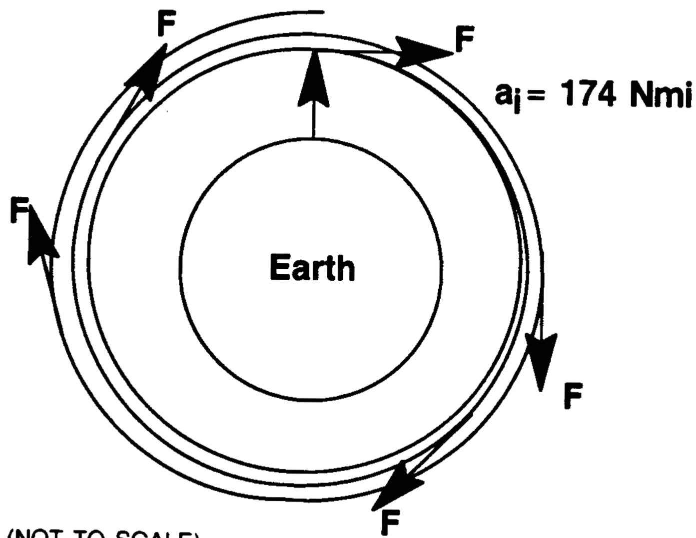
NOZZLE DIRECTIONS AND REBOOST PROFILE

The six thruster locations and directions were chosen to provide three-axis attitude control and low thrust reboost while minimizing plume impingement on the CDSF solar arrays. Control torque is coupled in +/- roll and uncoupled in +/- pitch and +/- yaw. Reboost is provided by yawing the CDSF 180 deg and firing two 0.1 lbf thrusters. Thrusters are sized to provide a reboost capability of 4.4 Nmi per day with an acceleration less than 10 micro-g during the continuous burn spiral reboost.

NOZZLE DIRECTIONS AND REBOOST PROFILE



CONTINUOUS BURN SPIRAL REBOOST



(NOT TO SCALE)

TORQUE	JET/DIR	JET/DIR	MOMENT ARM (M)
+ ROLL	A +Y	B −Y	4.3
− ROLL	A −Y	B +Y	4.3
+ PITCH	B +X		4.1
− PITCH	A +X		4.5
+ YAW	A −Y	B −Y	1.6
− YAW	A +Y	B +Y	1.6

F = 2 x .1 lbf Resistojets

Reboost acceleration < 10 micro-g

Reboost Capability: 4.4 Nmi / day

- REBOOST REQUIRES 180° YAW , JET FIRE A +X, B +X
- PLUME IMPINGEMENT MINIMIZED WITH JET LOCATION AND DIRECTION SELECTION

PROPULSION SIZING

The CDSF propellant system was sized to meet orbit altitude mission requirements and attitude control requirements. Orbit altitude mission requirements include a three year contingency lifetime, a nominal reboost scenario, right ascension of the ascending node (RAAN) adjustment, orbit phase angle adjustment, and rendezvous at preferred repeating orbit altitudes. Reaction Control System (RCS) jets are not primary for attitude control; however, RCS jets are required for thrust vector control during reboost.

PROPULSION SIZING

- **ORBIT ALTITUDE MISSION REQUIREMENTS**

  3 YEAR CONTINGENCY LIFETIME

  NOMINAL REBOOST SCENARIO

  RIGHT ASCENSION OF THE ASCENDING NODE (RAAN)

  ORBIT PHASE ANGLE ADJUSTMENT

  PREFERRED REPEATING ORBIT ALTITUDES

  174 Nm YIELDS A 48 HOUR PHASE REPEATING GROUND TRACK

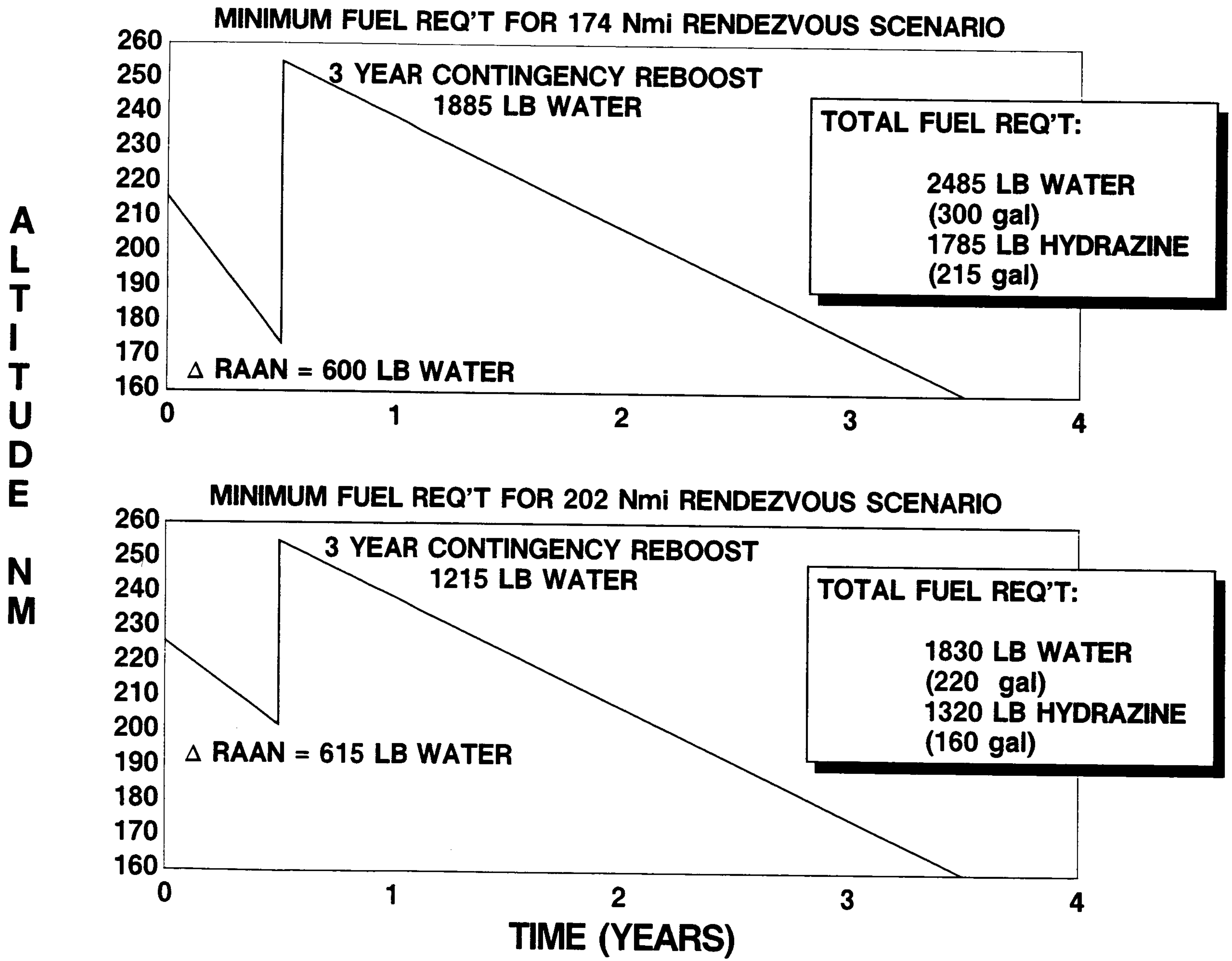
  202 Nm YIELDS A 72 HOUR PHASE REPEATING GROUND TRACK

- **ATTITUDE CONTROL REQUIREMENTS**

CDSF ORBIT ALTITUDE PROPELLANT REQUIREMENTS

Orbit altitude propellant requirements for a 3 year contingency reboost with RAAN adjustment are computed for both a 174 Nmi and 202 Nmi rendezvous altitude scenario. Mass and volume requirements for a hydrazine system are lower than for a water system.

CDSF ORBIT ALTITUDE PROPELLANT REQUIREMENTS

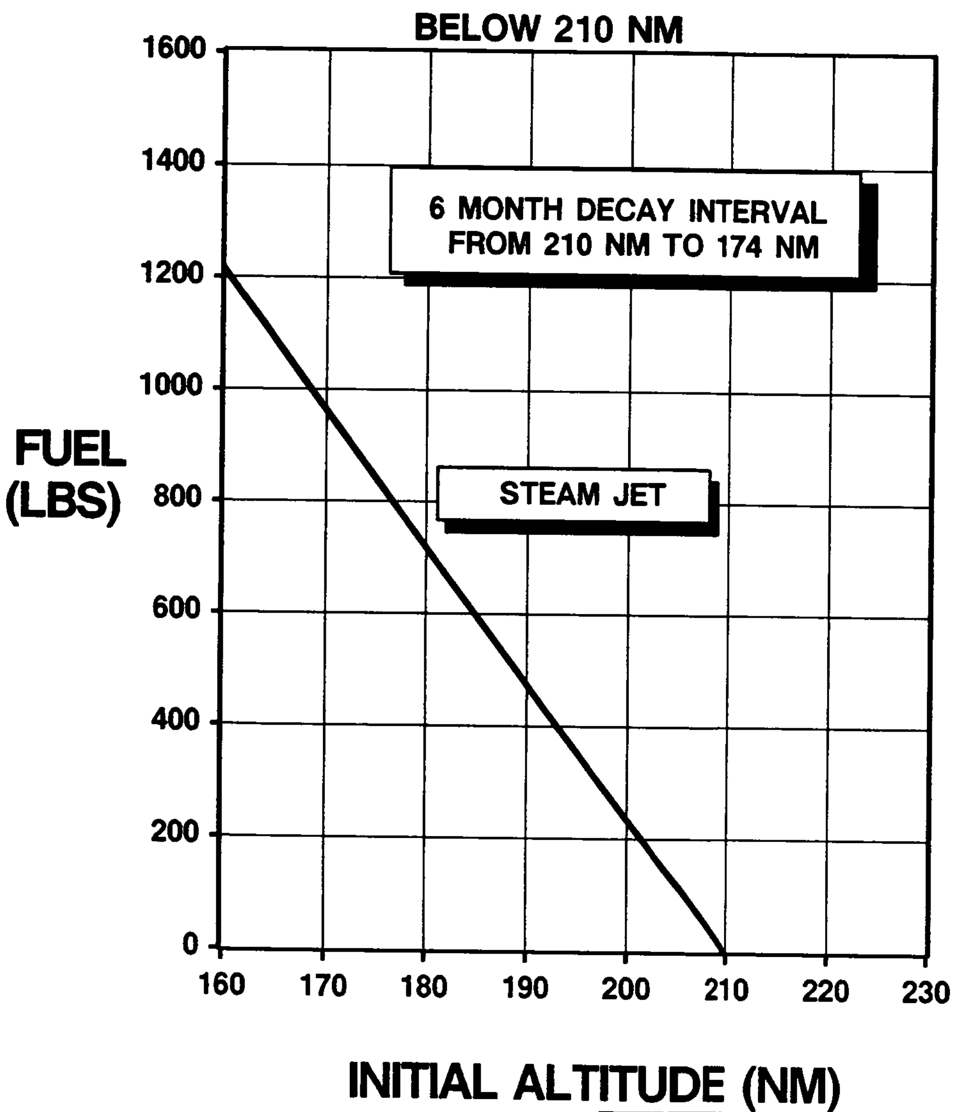


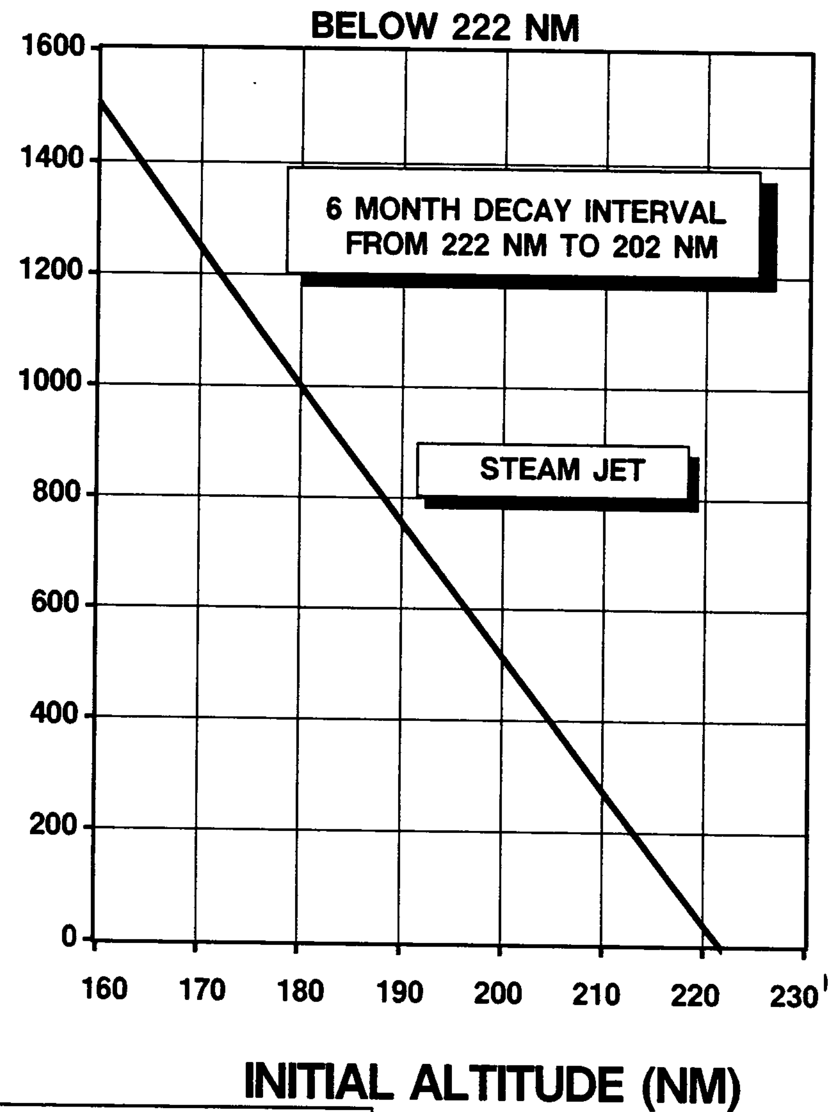
PROP REQT

ADDITIONAL FUEL FOR DEPLOYMENT

Additional fuel is required if the CDSF is deployed below 226 Nmi and must rendezvous at a preferred repeating orbit altitude of 202 Nmi six months later. Approximately 1400 lbs of additional water is required if the CDSF is deployed at 160 Nmi and must rendezvous at 202 Nmi six months later. Fuel requirements are lower for the 174 Nmi preferred repeating orbit rendezvous case.

100% CDSF ADDITIONAL FUEL FOR DEPLOYMENT





1000 LBS = 120 GALLONS = 16 FT**3

fuel 100

CDSF DEPLOYMENT ALTITUDE

The CDSF deployment altitude affects both STS lift capacity and CDSF orbit reboost fuel requirements. A low deployment altitude maximizes STS lift capacity but increases CDSF orbit reboost fuel requirements. A high deployment altitude minimizes CDSF orbit reboost fuel requirements but decreases STS lift capacity.

CDSF DEPLOYMENT ALTITUDE

LOW DEPLOYMENT ALTITUDE MAXIMIZES STS LIFT CAPACITY

- 1000 LB FOR EACH 10 Nm ALTITUDE DEPLOYMENT REDUCTION

HIGH DEPLOYMENT ALTITUDE MINIMIZES CDSF ORBIT REBOOST PROPELLANT REQUIREMENTS

- 200 LB FOR EACH 10 Nm ALTITUDE DEPLOYMENT INCREASE

EXAMPLE:

216 Nm CDSF DEPLOYMENT REQUIRES 2485 LB H_20 PROPELLANT FOR THE 174 Nm RENDEZVOUS ALTITUDE SCENARIO

160 Nm CDSF DEPLOYMENT REQUIRES 3685 LB H_20 PROPELLANT BUT STS LIFT CAPACITY INCREASES BY 5600 LB

PROPELLANT REQUIREMENTS FOR ATTITUDE CONTROL

Since the CDSF free flyer with a small momentum wheel (150 Nms) is gravity gradient stable within 5 deg, the CDSF RCS jets are not primary for attitude control. The RCS jets are required for thrust vector control during reboost.

PROPELLANT REQUIREMENTS FOR ATTITUDE CONTROL

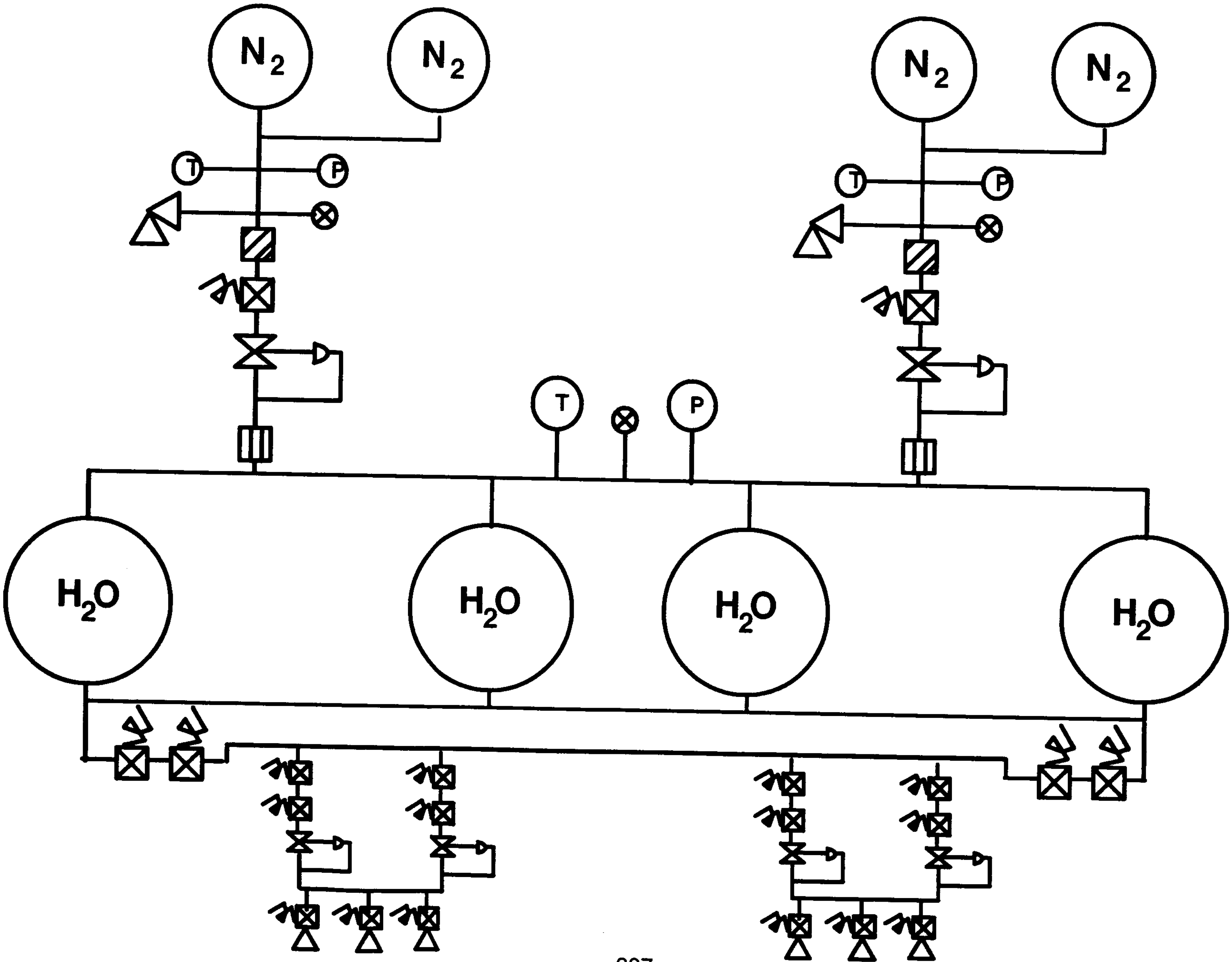
- RCS JETS ARE NOT PRIMARY FOR CDSF FREE FLYER ATTITUDE CONTROL
  - ARRAYS ALONG VELOCITY WITH GG BOOM ALONG NADIR IS STABLE

- RCS JETS ARE REQUIRED FOR THRUST VECTOR CONTROL DURING REBOOST
  - 10% REBOOST FUEL BUDGETED FOR TVC

CDSF PROPULSION SYSTEM

A CDSF propulsion system schematic illustrates the H2O system which is pressurized with four nitrogen tanks. Six resistojets with heaters are fed by four water tanks.

CDSF PROPULSION SYSTEM



PROPULSION SYSTEM WEIGHT

A weight breakdown for the CDSF Concept 1 propulsion system allocates a total system weight of 4867 lbs.

PROPULSION SYSTEM WEIGHTS

RESISTOJETS (6)	51
PROPELLANT TANKS (4)	231
N2 TANKS (4)	246
LINES, VALVES, REGULATORS, ETC	85
TEMPERATURE REGULATION	34
SUBTOTAL	647
CONTINGENCY (15%)	97
PRESSURANT (N2)	69
PROPELLANT (H20)	3685
10% THRUST VECTOR CONTROL	369
TOTAL	4867

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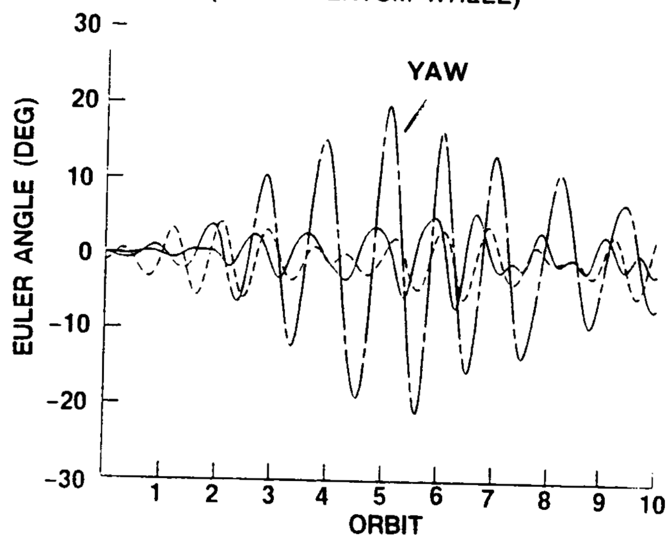
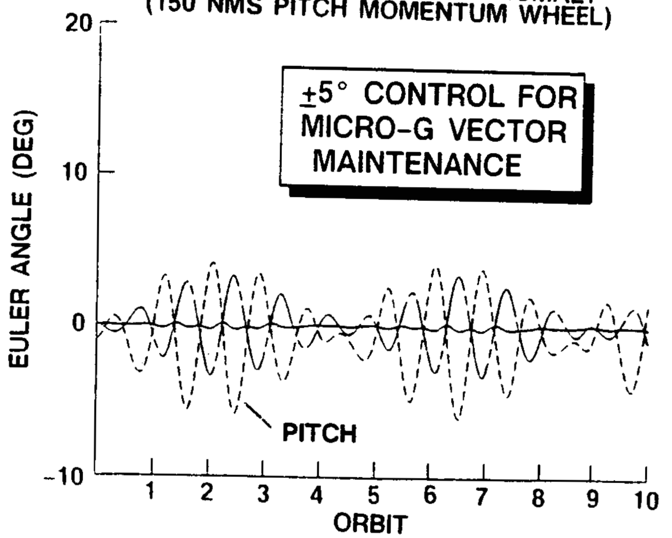
6.1.2.5. STABILIZATION, GUIDANCE, AND NAVIGATION SYSTEM

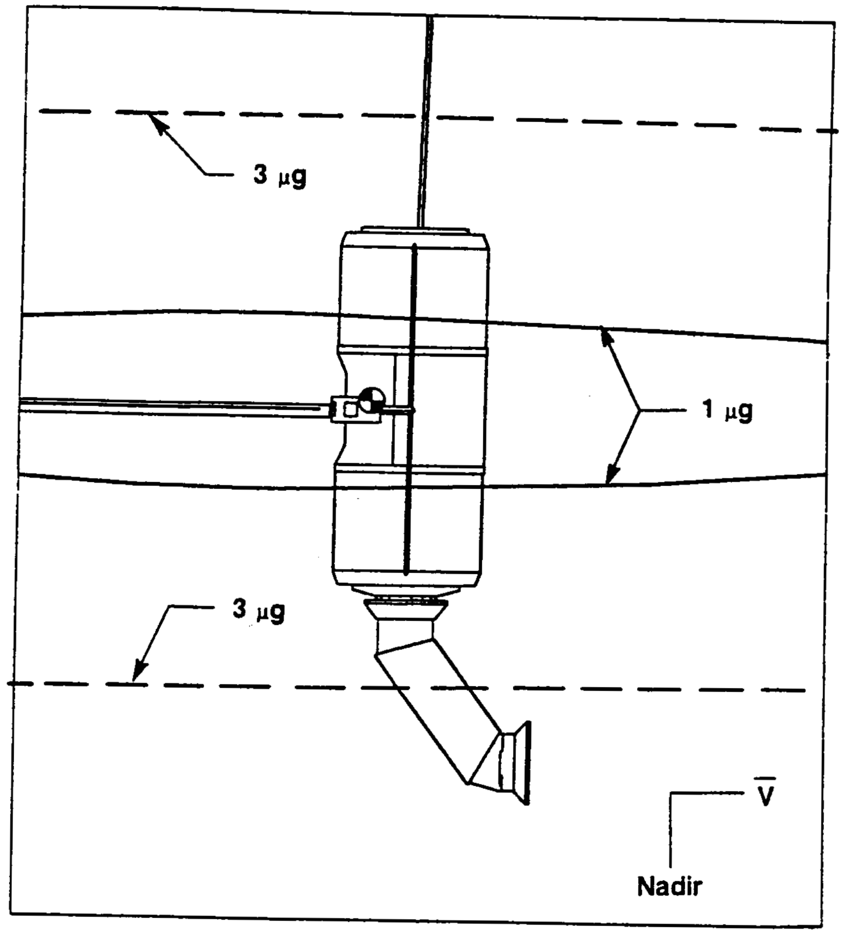
FREE FLYER MICRO-G FLIGHT STABILITY ANALYSIS

The free flying CDSF exhibits an attitude stability of $\pm$ 20 deg without a momentum wheel and $\pm$ 5 deg with a 150 Nms pitch momentum wheel when flying with arrays trailing in the minus V-bar direction. The center of mass is located in the CDSF lab center, and the entire CDSF experiment laboratory section is within 1 micro-g at an altitude of 180 Nmi on March, 1993.

FREE FLYER MICRO-G FLIGHT STABILITY ANALYSIS







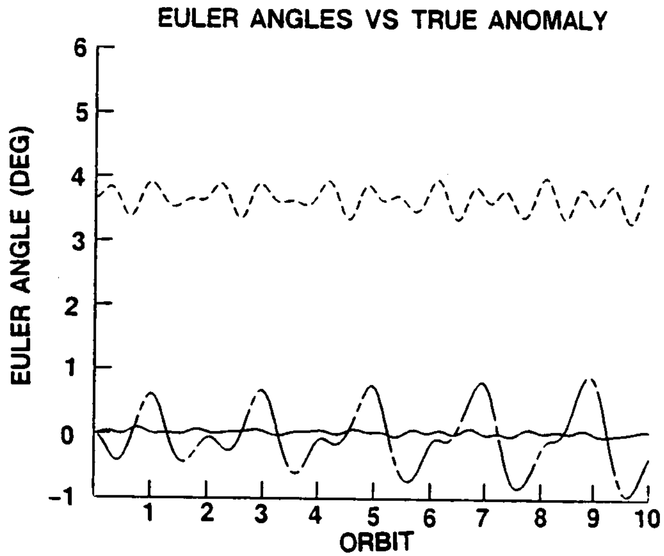
BEST ESTIMATE MSFC/J70 ATMOSPHERE
SOLAR FLUX = 131, AP = 20.7
ALTITUDE = 180 NMI
PITCH DRIFT RATE = ±0.005 DEG/SEC
DATE = MARCH 1993

CREW TENDED MICRO-G FLIGHT STABILITY ANALYSIS

The crew tended CDSF exhibits a gravity gradient attitude stability of $\pm$ 1 deg when oriented in the depicted attitude. The center of mass is located in line with the CDSF lab center, and the entire CDSF experiment module is within 3 micro-g at an altitude of 180 Nmi on March, 1993.

CREW TENDED MICRO-G FLIGHT STABILITY ANALYSIS

- GRAVITY GRADIENT ASSISTED PASSIVE STABILIZATION



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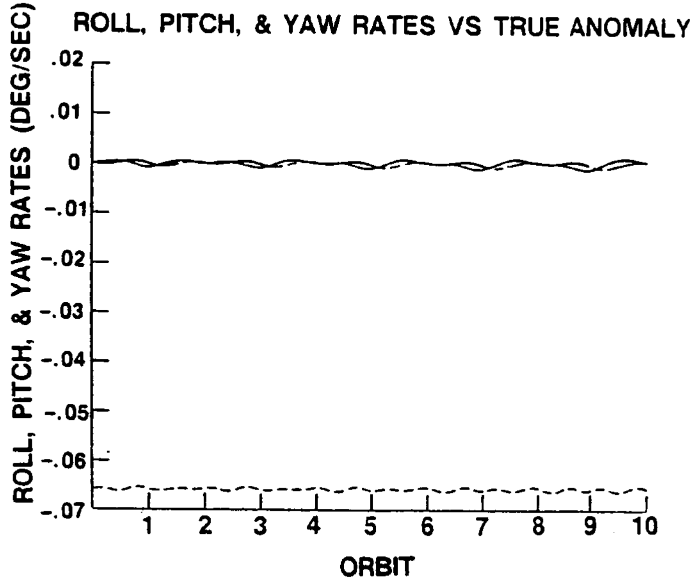
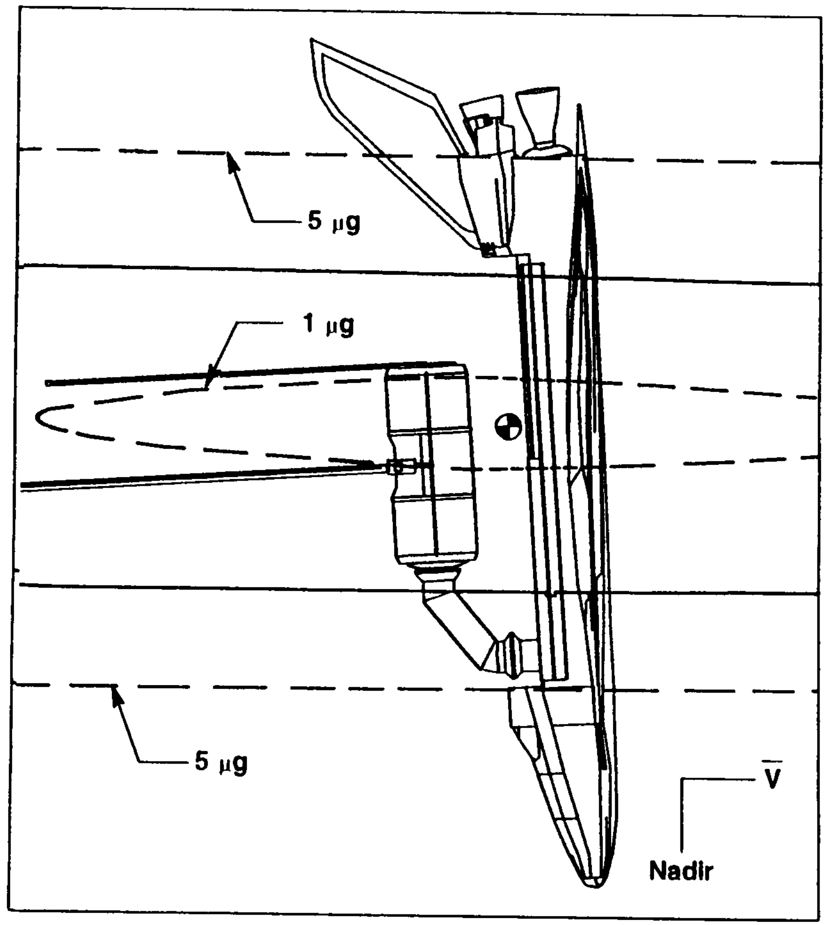


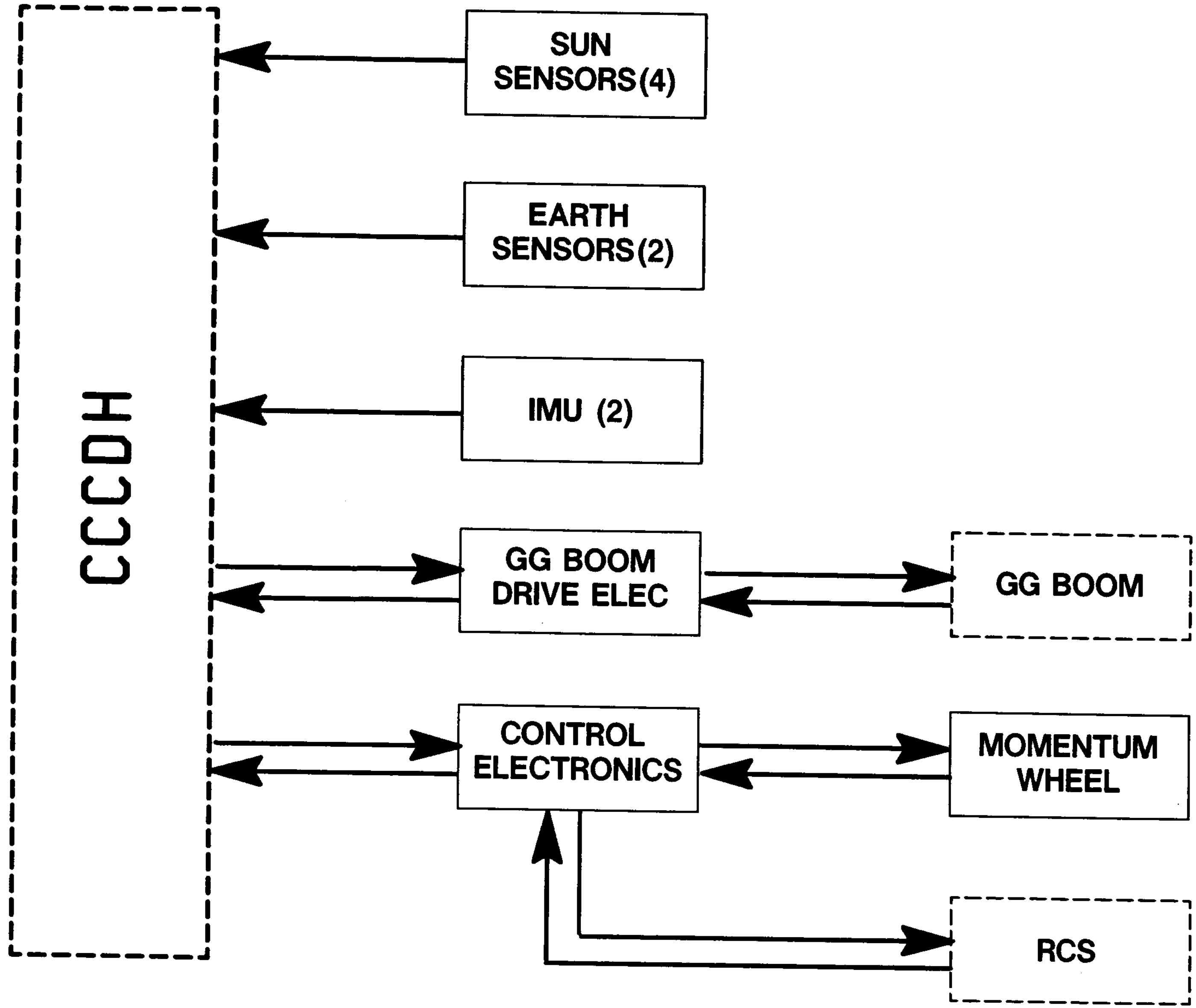


BEST ESTIMATE MSFC/J70 ATMOSPHERE
SOLAR FLUX = 131, AP = 20.7
ALTITUDE = 180 NMI
PITCH DRIFT RATE = ±0.005 DEG/SEC
DATE = MARCH 1993

GUIDANCE, NAVIGATION, AND CONTROL SUBSYSTEM SCHEMATIC

The CDSF GN&C schematic illustrates the components that make up the subsystem which consist of the sun sensors, Earth sensors, Inertial Measurement Units (IMUs), gravity gradient boom drive electronics, and the control electronics interface to the Command, Control, Communication, and Data Handling (CCC&DH) system central computer.

GN&C SUBSYSTEM SCHEMATIC



GUIDANCE, NAVIGATION, AND CONTROL WEIGHTS

A weight definition for the CDSF GN&C system illustrates the component breakdown of the 190 lb total system weight.

GUIDANCE, NAVIGATION, AND CONTROL WEIGHTS

SUN SENSORS (4)	1
EARTH SENSORS (2)	9
IMU (2)	14
MOMENTUM WHEEL	60
CONTROL ELECTRONICS	43
GG BOOM DRIVE ELECTRONICS	21
MISC	17
SUBTOTAL	165
CONTINGENCY (15%)	25
TOTAL	190

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6.1.2.6. COMMUNICATION, COMMAND, CONTROL AND DATA HANDLING SYSTEM

COMMUNICATIONS & DMS REQUIREMENTS

This section describes the concept and sizing description of the CDSF communications, command, control and data handling system referred to as CCCDHS in section 6.1.2 of this report. Only a summary description is provided on the following pages. Section 9.3 of this report provides a detailed description of the end to end CDSF mission data handling system (MDHS) concept which includes both the CDSF on-board system and the ground data handling and flight control system.

A summary of the requirements per the CDSF MDHS conceptual system analysis performed as part of this study and described in section 9.0 is presented here. A functional block diagram is depicted and a component level weight break down is described.

COMMUNICATION & DMS REQUIREMENTS

- 16 KBPS CAN SATISFY DERIVED MISSION SCENARIOS FROM CANDIDATE EXPERIMENT LIST

- 50 TO 75 % OF CANDIDATE EXPERIMENTS IN DERIVED CREW–TENDED MISSION SCENARIOS REQUIRE VIDEO (~ 50 MBPS)

- 15% OF FREE FLYER MISSION SCENARIO EXPERIMENT CANDIDATES REQUIRE VIDEO

  -- REQUIRE OCCASIONAL FRAME SNAPSHOTS AT ~ 1 MBPS/C

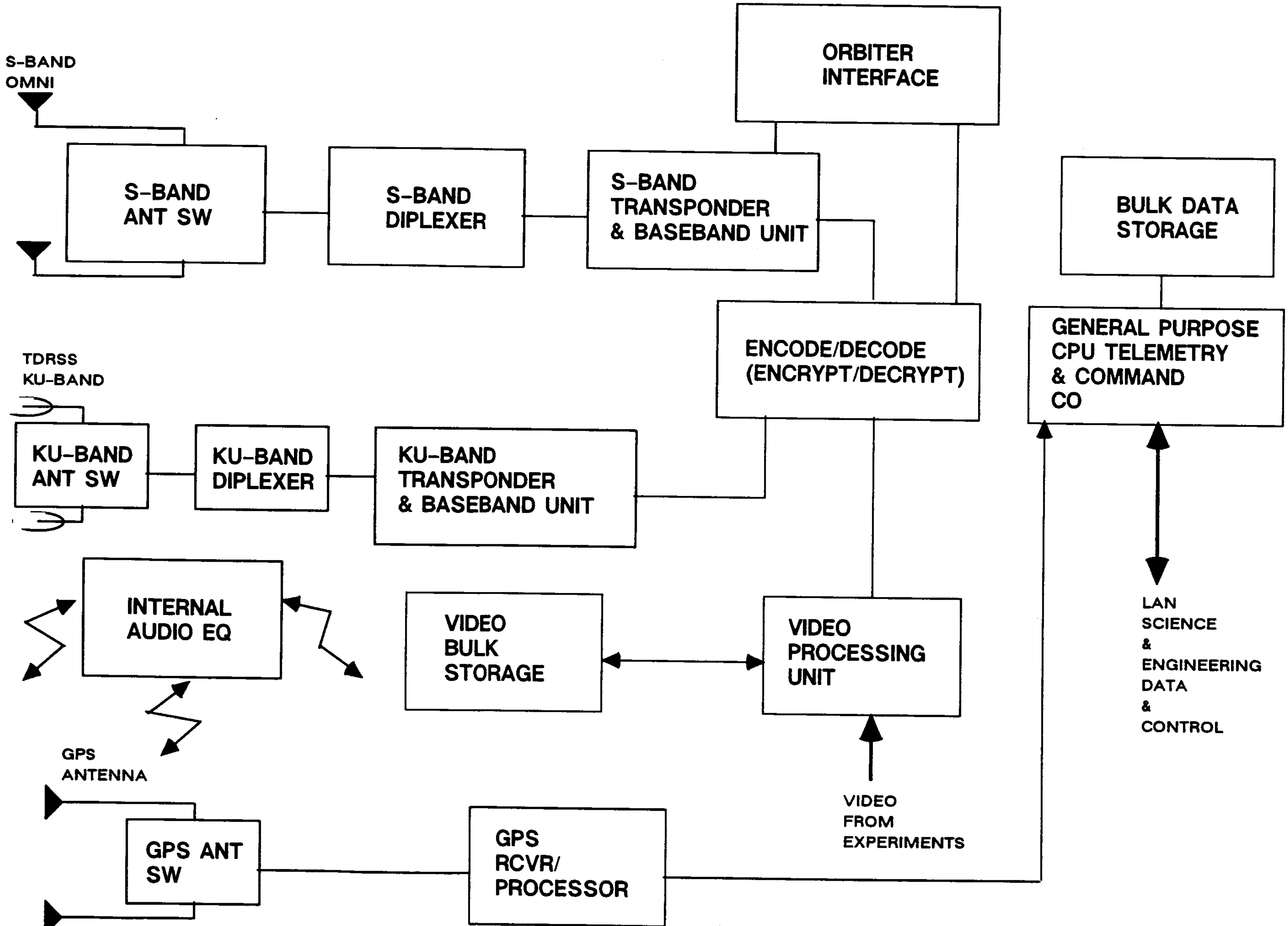
  -- EXCEEDS TDRSS MULTIPLE ACCESS S–BAND LINK

COMMUNICATION & DMS REQUIREMENTS

(CONCLUDED)

- STS ATTACHED CREW–TENDED OPERATONS AT 16 KBPS FOR DIGITAL DATA AND 50 MBPS VIDEO DATA ARE WITHIN STS CAPABILITIES
  - -- NO SPECIAL CDSF HARDWARE REQUIRED
- FREE FLYER EXPERIMENT CANDIDATES ARE HIGHLY AUTOMATED
  - -- COMMAND CONTROL REQUIREMENTS MINIMAL
  - -- 16 KBPS DIGITAL DATA RATE TDRSS COMPATIBLE
  - -- SNAP SHOT VIDEO CAN BE ACCOMMODATED WITH ON BOARD STORAGE
- ATTACHED AND FREE FLYER MODES ARE BOTH POSSIBLE WITH STANDARD NASA STS AND NASA POCC OR NASA POCC/USER REMOTE FACILITIES (FREE FLYER MODE)

COMMUNICATIONS, COMMAND, CONTROL & DATA HANDLING



ccdh

COMMUNICATIONS, COMMAND, CONTROL, & DATA HANDLING

BULK DATA STORAGE (2)	25
COMPUTERS (2)	43
TDRSS TRANSPONDERS (2)	25
TDRSS POWER AMPL (2)	10
TDRSS RF SWITCH (2)	2
KU-BAND HIGH GAIN ANT. (2)	10
KU-BAND GIMBAL DRIVE ELEC. (2)	20
KU-BAND ANTENNA GIMBAL MECH. (2)	34
KU-BAND DIPLEXER (2)	2
S-BAND OMNI ANTENNA (2)	2
S-BAND DIPLEXER (2)	2
S-BAND TRANSPONDER	25
S-BAND POWER AMP	8
ENCODER/DECODER	17
GPS ANTENNA (2)	2
GPS ANTENNA SWITCH (2)	2
GPS RCVR/PROCESSOR (2)	10
VIDEO PROCESSING UNIT (2)	21
VIDEO BULK STORAGE (2)	17
INTERNAL AUDIO UNIT	30
RF CABLES & WAVE GUIDES	55
SUBTOTAL	362
CONTINGENCY (15%)	54
TOTAL	416

6.1.2.7. STRUCTURAL DESIGN DESCRIPTION

CDSF STRUCTURAL CONFIGURATION

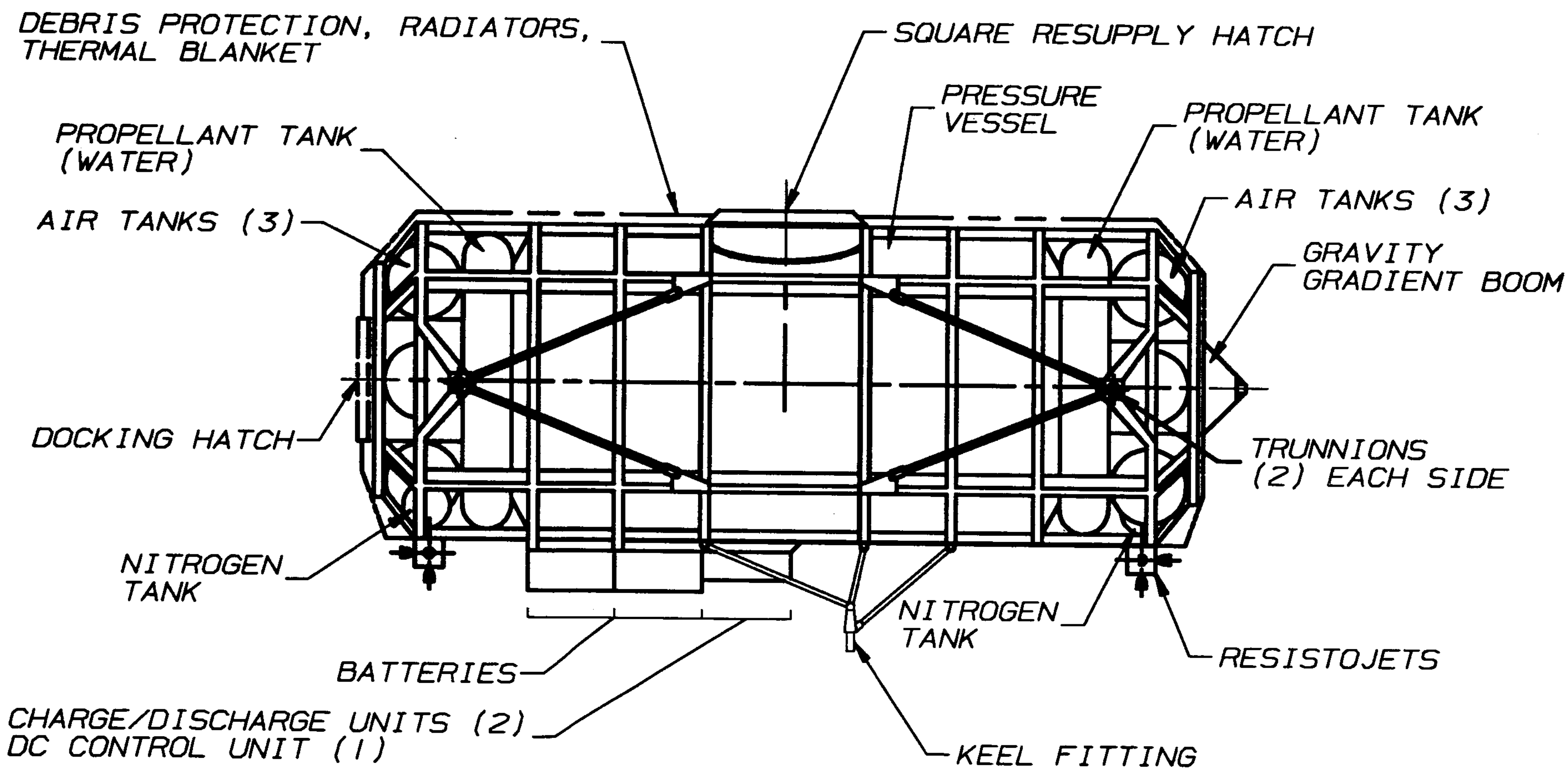
The pressure vessel was sized shorter than the total modular length of 30 feet. Dual propellant (water) torus shaped tanks and spherical air tanks were located fore and aft of the pressure shell. Structural ring and longeron members were extended to provide attachment hard points for these tanks as well as for body mounted radiators, thermal blanketing, micrometeoroid/debris shielding, gravity gradient boom, and resistojets. A short access tunnel allows access between the pressure shell and docking hatch.

A 46 inch square resupply hatch and berthing ring were located amidship for easy transition of racks between the module and resupply module. A two piece square hatch design similar to the two piece hatch used between the command module and the LEM on the Apollo missions was suggested due to the close proximity and possible interference between the experiment racks and berthing hatch.

The primary structure consists of six ring frame (further evaluation might concede that four rings are sufficient) to support the pressure shell and two additional rings for the fore and aft extensions. Six longerons were located radially about the module. Four trunnions and one keel pin provide support within the orbiter.

The pressure shell would be defined similar to that used in Space Station proposals: a waffle grid on the exterior of welded aluminum panels. This provides stabilization of the shell's skin and allows a smooth inside wall. The pressure shell is capped with conical end domes, one side connecting to the access tunnel leading to the docking hatch. Debris and radiation protection were defined as an aluminum bumper scheme and multi-layer insulation.

CDSF CONCEPT #1 STRUCTURAL CONFIGURATION



CDSF1STRUCTCONFIG

STRUCTURAL WEIGHT BREAKDOWN

A structural weight breakdown for the experiment module is provided. Note that the weight for the gravity gradient boom has been classified as structure.

STRUCTURES

PRIMARY STRUCTURE	5375
SECONDARY STRUCTURE	1782
HATCH AND MECHANISMS	1090
RACKS AND MOUNTINGS	1450
MODULAR CONTAINERS	550
MAN SYSTEMS HARDWARE	85
GRAVITY GRADIENT BOOM	425
SUBTOTAL	10757
CONTINGENCY (15%)	1613
TOTAL	12370

Solar Array Structural Dynamics Analysis

The objective of this part of the study was to determine structural dynamics responses of the Solar Arrays which are attached to the rigid CDSF. Two cofigurations were evaluated : 1) CDSF free-flier, and 2) CDSF with docked Orbiter.

A finite element model (FEM) required for this analysis was generated. The solar arrays were modeled by flexible elements. The CDSF and the Orbiter were modeled as rigid bodies with inertia properties defined in Section 5.2.1.4. The solar array is modeled as a 19 meter cantilever beam with mass 318 kg. The bending stiffness is 5.05E5 N-m**2 and the torsional stiffness is 0.11 E5 N-m**2. The first bending and torsional natural frequencies of the solar array are 0.269 Hz and 1.02 Hz respectively.

CDSF FREE FLYER, ARRAYS PARALLEL

Mode	Frequency (Hz)	Description
1	0.269	Bending
2	0.275	Bending
3	0.285	Bending
4	0.349	Bending
5	1.02	Torsion
6	1.02	Torsion
7	1.66	Bending
8	1.67	Bending
9	1.67	Bending
10	1.68	Bending
11	3.06	Torsion
12	3.06	Torsion
14	4.54	Bending
15	4.55	Bending

Freq. Free Flyer – PV vert.

Solar Array Normal Mode Analysis

Two array configurations were considered. One configuration had the arrays perpendicular to the CDSF center line, and the other configuration had the arrays parallel to the CDSF center line. The first fifteen natural frequencies of the CDSF-array assembly with arrays perpendicular are shown. It is considered that the lowest structural frequency of 0.272 Hz is high enough to prevent adverse control system interaction.

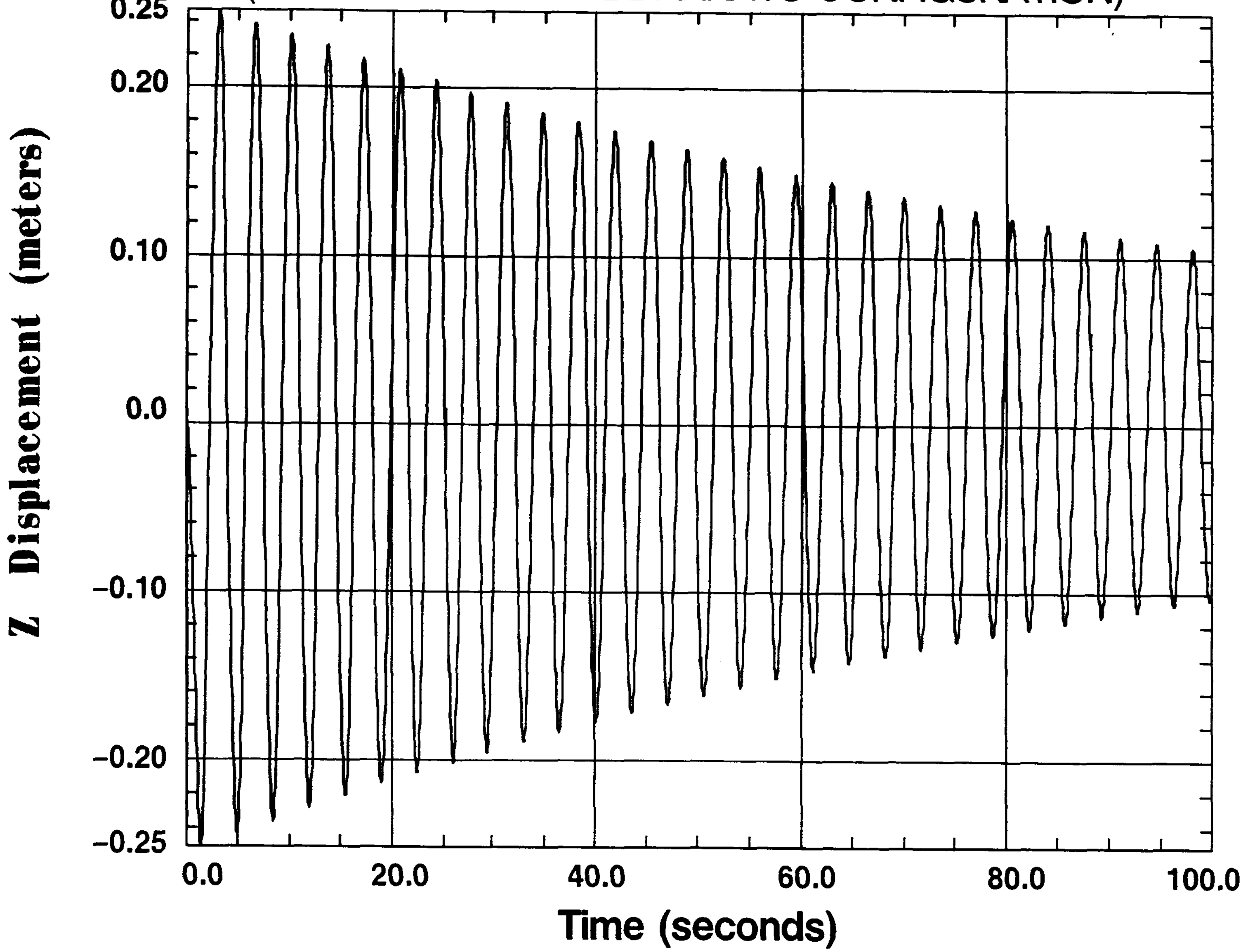
CDSF FREE FLYER, ARRAYS PERPENDICULAR

Mode	Frequency (Hz)	Description
1	0.272	Bending
2	0.272	Bending
3	0.303	Bending
4	0.508	Bending
5	1.02	Torsion
6	1.02	Torsion
7	1.67	Bending
8	1.67	Bending
9	1.68	Bending
10	1.98	Bending
11	3.06	Torsion
12	3.06	Torsion
14	4.55	Bending
15	4.55	Bending

Solar Array Forced Response Analysis

Responses of solar arrays to two excitation sources were studied: the CDSF free–flier was exposed to a hard Orbiter docking, and the CDSF–Orbiter configuration was excited by VRCS jet fire. The docking excitation is modeled as a square pulse of 500 lbf and 1 second duration. The two Orbiter rear VRCS jets fired a single burst of 0.04 seconds square pulse and 25 lbf each. Transient response of the solar array tip displacement for the CDSF with parallel array configuration and Orbiter hard docking excitation is shown. Maximum tip deflection is 0.25 meters. Maximum displacement at solar array tip for perpendicular array configuration is 0.13 meters, and for CDSF–Orbiter configuration is 0.07 millimeters. With the length of the flexible portion of the array 19 meters, these displacement magnitudes require further investigation of the impact on the array structural integrity.

Orbiter Hard Dock
SOLAR ARRAY TIP RESPONSE
(CDSF WITH PARALLEL ARRAYS CONFIGURATION)



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SOLAR ARRAY STRUCTURAL DYNAMIC RESPONSE

STRUCTURAL DYNAMIC CHARACTERISTICS DETERMINED (NATURAL MODES, FREQUENCIES) AND TWO EXCITATIONS STUDIED:

- **ORBITER HARD DOCK**

  MAX DISPLACEMENT AT SOLAR ARRAY TIP = 0.25 METERS.

- **VRCS JET FIRE**

  MAX DISPLACEMENT AT SOLAR ARRAY TIP = 0.07 mm.

NO STRUCTURAL INTERFERENCE IDENTIFIED

NOTE: IMPACT OF TIP DISPLACEMENT ON ARRAY STRUCTURAL INTEGRITY REQUIRES FURTHER INVESTIGATION

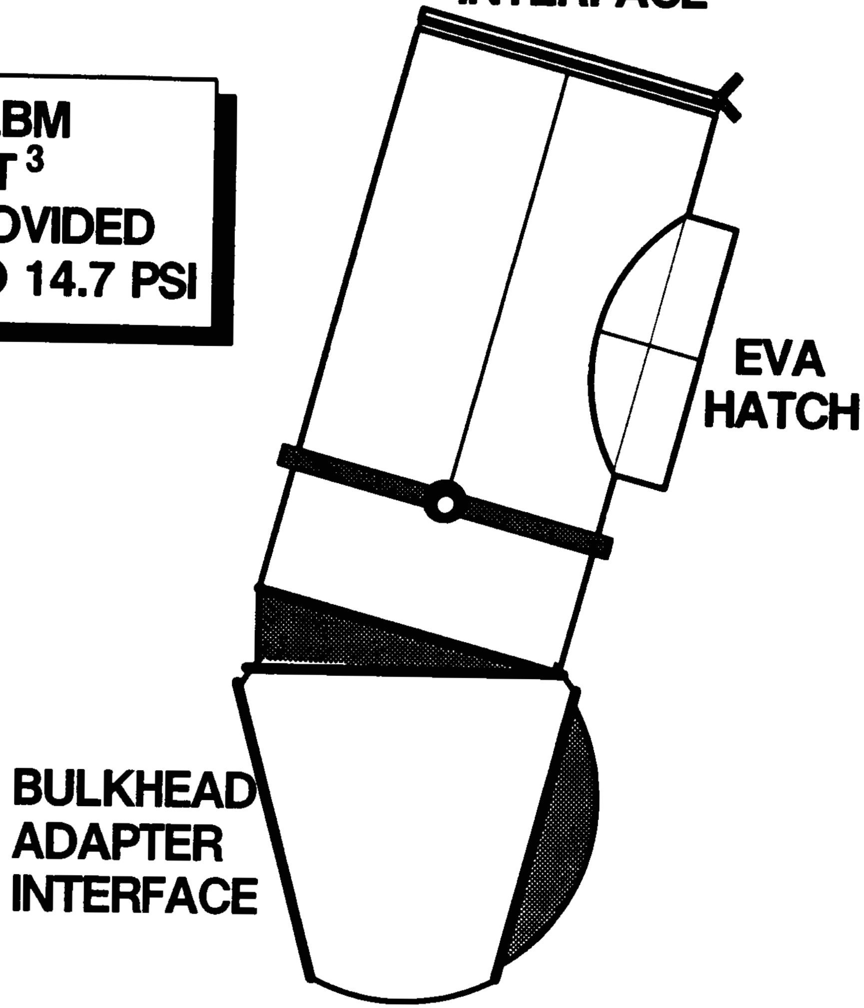
6.1.3. DOCKING MODULE DESCRIPTION

DOCKING SYSTEM

The CDSF docking system performs several functions. The docking system provides the final guiding and mechanical connections between the CDSF and the orbiter for berthing. It provides the necessary utility interfaces between the CDSF and the orbiter and also allows for passage of crew and equipment in a "shirt sleeve" environment. EVA access is also provided through a hatch on the upper part of the docking system. When connected to the STS provided bulkhead adapter interface, the docking system extends about eight feet into the orbiter cargo bay.

CDSF DOCKING SYSTEM

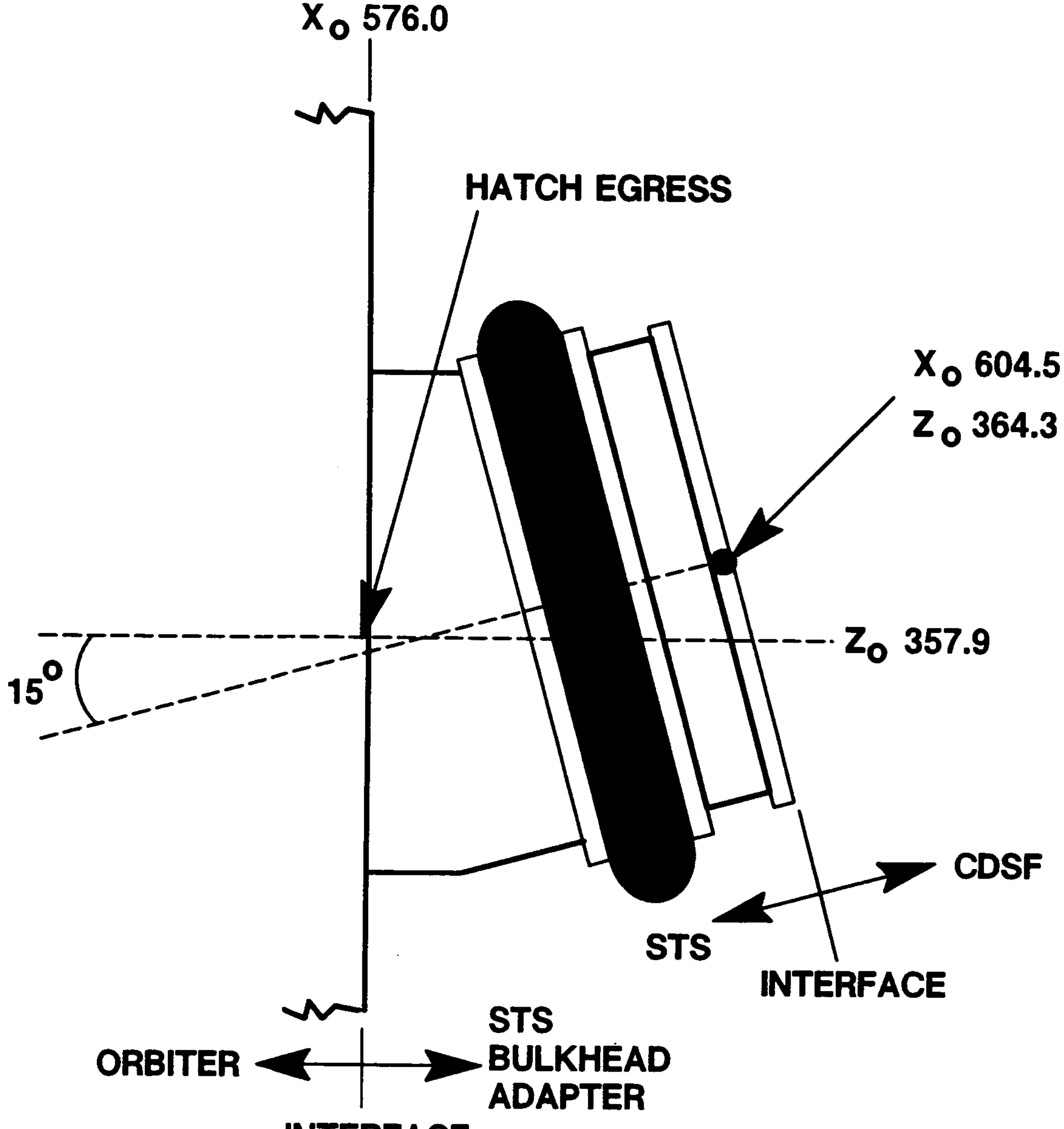
WEIGHT = 2440 LBM
VOLUME = 240 FT^3
EVA ACCESS PROVIDED
PRESSURIZED TO 14.7 PSI



STS BULKHEAD ADAPTER

The NSTS side of the docking interface will be an NSTS-provided bulkhead adapter which will provide all active functions for establishing the pressure-tight interface with the CDSF side of the interface.

STS BULKHEAD ADAPTER



BULK

DOCKING SYSTEM WEIGHT BREAKDOWN

A breakdown of the docking subsystem weights is given. The largest single entity is the weight of the pressure vessel structure (750 lbms). The next largest weight is the berthing mechanism (353 lbms). The restraint assembly (structure used to attach to longeron and keel fittings) is 331 lbms and the air revitalization system is 269 lbms.

DOCKING SYSTEM WEIGHT BREAKDOWN

STRUCTURE	750
AIR REVITALIZATION	269
FIRE DECT. AND REPRESS. SYS	50
ELECTRICAL	112
MLI INSTALLATION	86
AUDIO/VIDEO	17
CAUTION AND WARNING	22
BERTHING MECH ACTIVE ASSY.	353
EXTERNAL UMBILICAL ASSY.	88
RESTRAINT ASSEMBLY	331
HAND AND FOOT RESTRAINTS	34
SUBTOTAL	2122
CONTINGENCY (15%)	319
TOTAL	2441

DSWEIGHT

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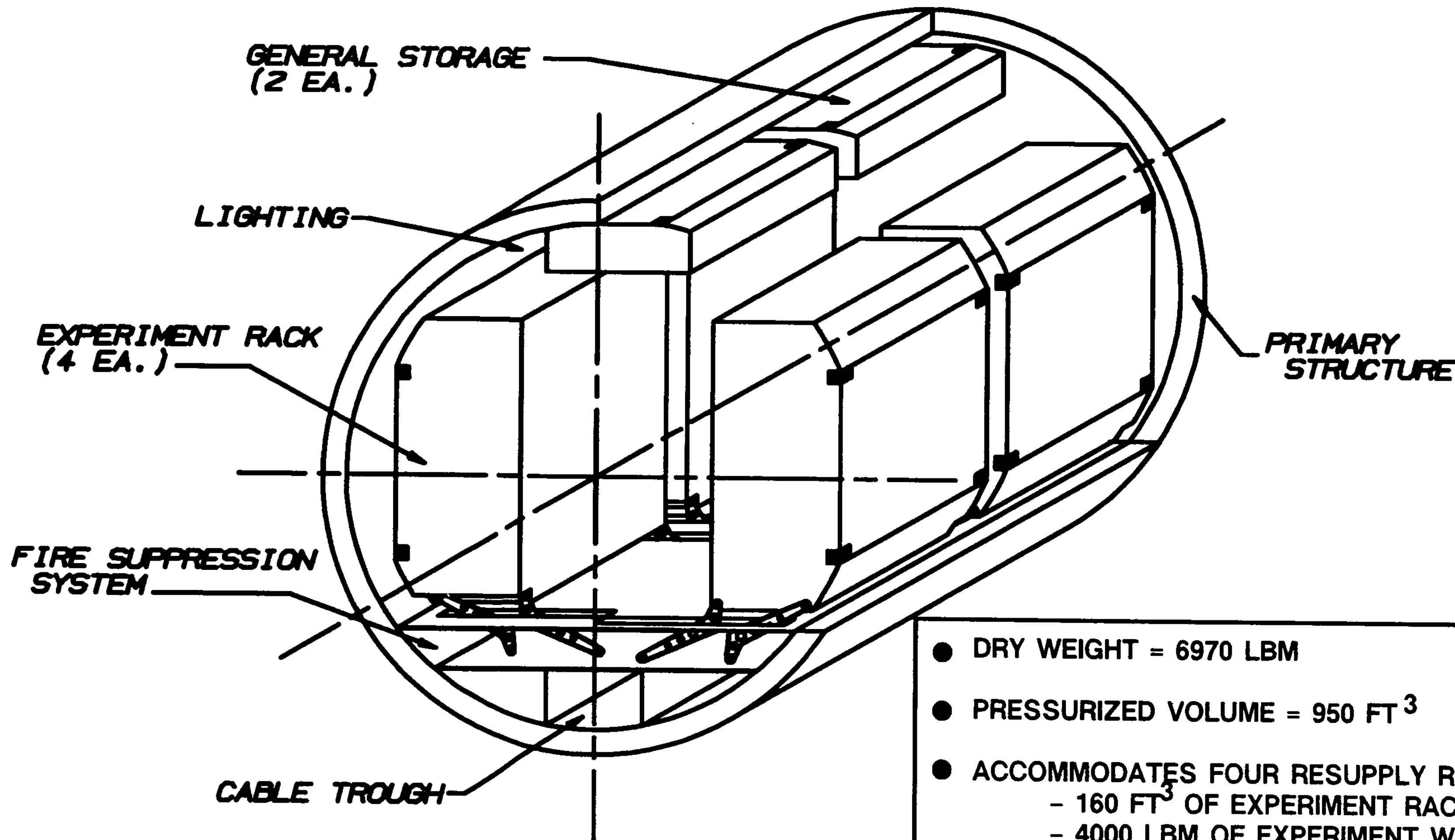
6.1.4. RESUPPLY MODULE DESCRIPTION

CDSF RESUPPLY MODULE

The resupply module is used to change out experiment racks from the CDSF and to resupply the CDSF with consumables such as air and water. Four double experiment racks with a total volume of 160 cubic feet and 4000 lbms of payload can be accommodated in the resupply module along with 1200 lbms of water and a three year supply of air.

CDSF RESUPPLY MODULE

SYSTEMS CONFIGURATION

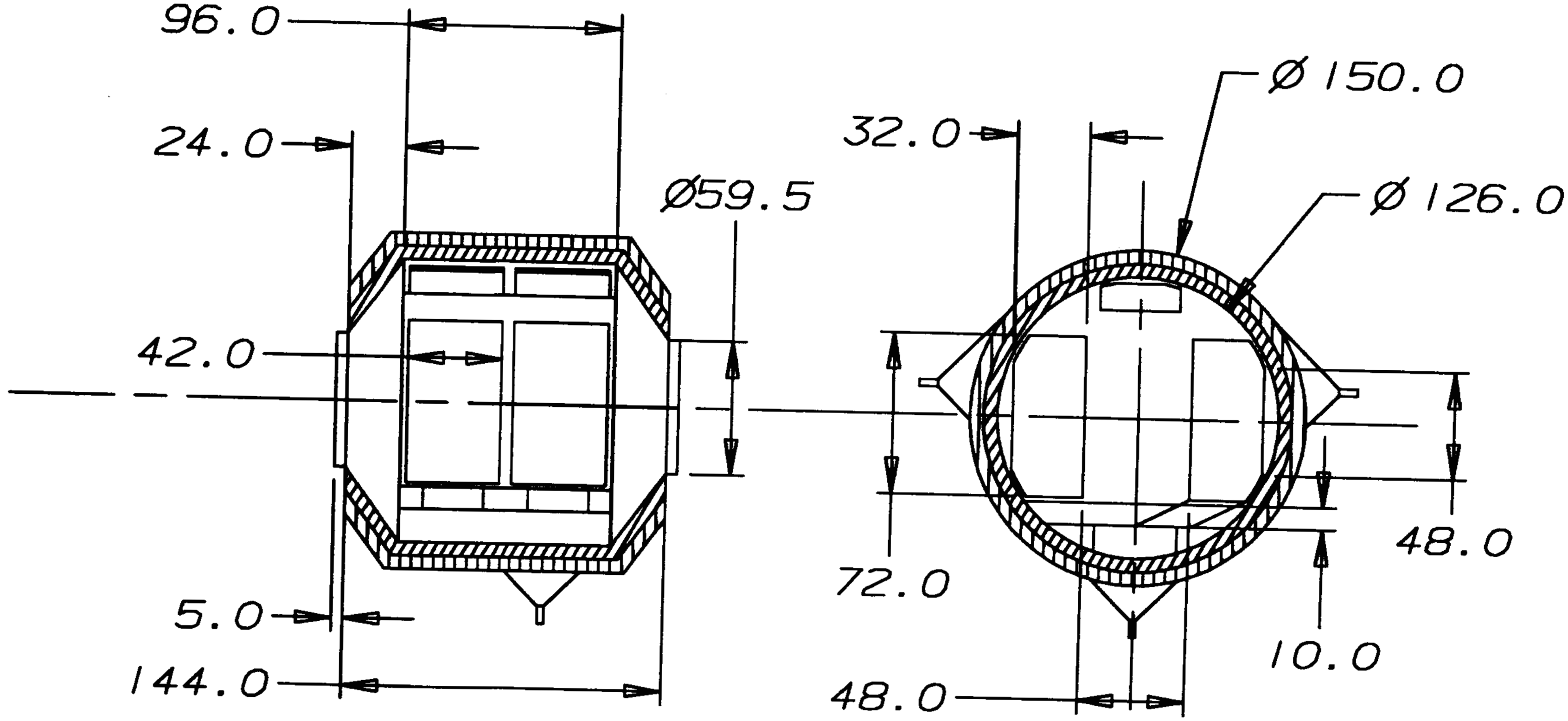


- DRY WEIGHT = 6970 LBM
- PRESSURIZED VOLUME = 950 FT^3
- ACCOMMODATES FOUR RESUPPLY RACKS;
  - 160 FT^3 OF EXPERIMENT RACKS
  - 4000 LBM OF EXPERIMENT WEIGHT
- THREE YEAR AIR SUPPLY CAPACITY
- 1200 LBM WATER CAPACITY
- 14.7 PSI INTERNAL PRESSURE

RESUPPLY MODULE AND RACK DIMENSIONS

The resupply module is constructed out of the same 12.5 foot diameter cylindrical structure as the experiment module. It has a length of 12 feet with a 46" square hatch at one end mounted in a 59.5" diameter end plate. Two sets of side by side CDSF double racks (72" tall by 42" wide by 32" deep) are mounted on four bar linkage mechanisms identical to those in the CDSF laboratory section so that rack transfer can be accomplished with as little effort as possible.

RESUPPLY MODULE AND RACK DIMENSIONS



ALL DIMENSIONS IN INCHES

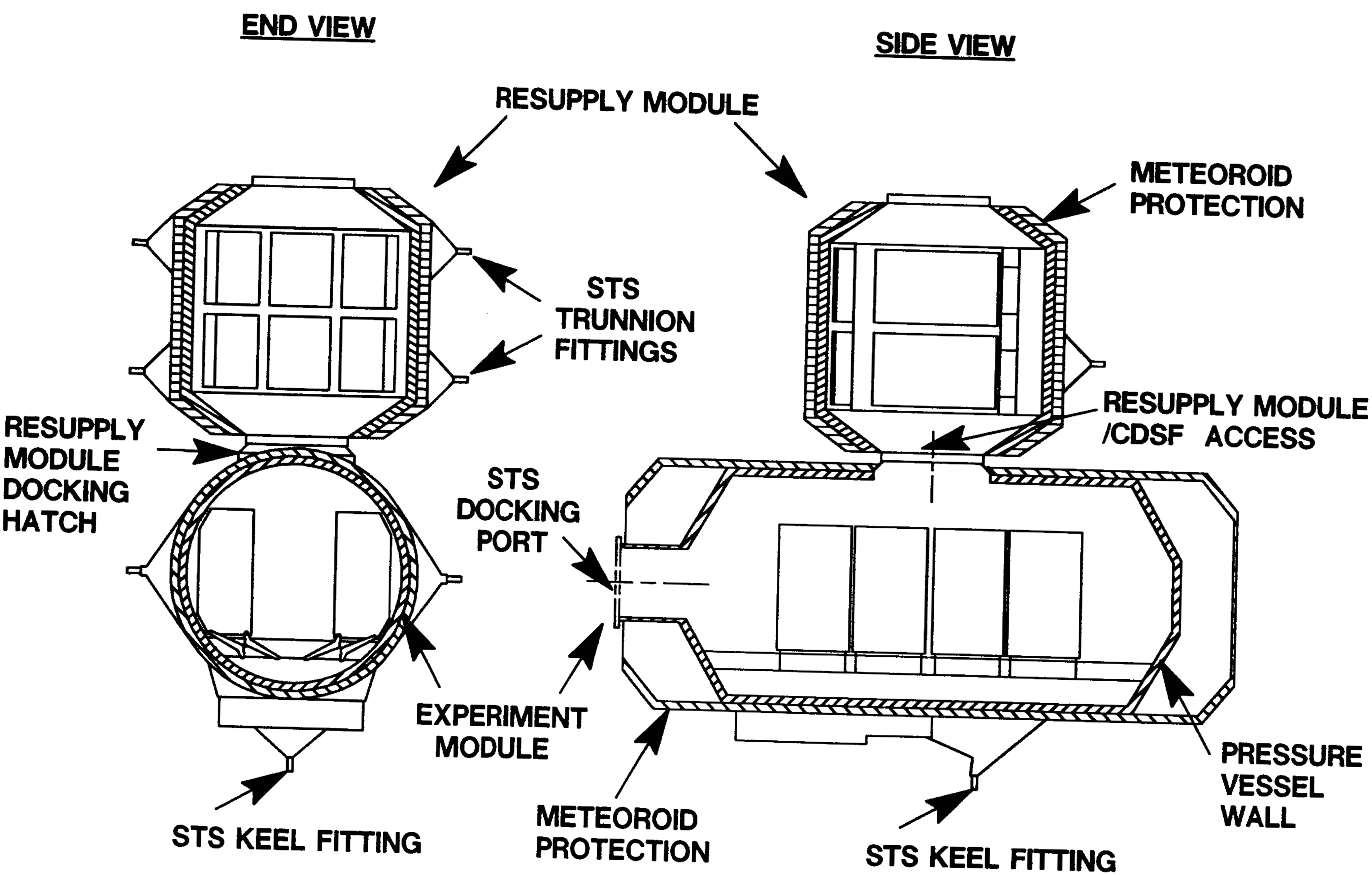
RESDIM

CDSF RESUPPLY MODULE AND STRUCTURE

The resupply module has the same pressure shell and meteoroid protection as the full size CDSF module. During resupply operations, the resupply module is connected to the hatch on top of the CDSF. Each change out rack in the resupply module is then rotated away from the pressure vessel wall via a four bar linkage, disconnected then rotated 90 degrees and passed through the hatch into the experiment module where it is installed. Corresponding racks in the CDSF are passed through the hatch into the resupply module, rotated 90 degrees then installed. Once the appropriate racks have been exchanged, the resupply module can be detached from the CDSF and placed in the orbiter cargo bay or it can be left on orbit still attached.

CDSF RESUPPLY MODULE STRUCTURE

SHOWN BERTHED TO THE CDSF



RESTRUC

RESUPPLY MODULE WEIGHT BREAKDOWN

A complete weight breakdown for the resupply module has been calculated. Weight included in the primary structure is mostly the pressure vessel. Secondary structure includes items such as ribs, stringers and floorings. The berthing mechanism active assembly includes the hatch, bulkhead and latches. Racks and mountings constitute the rack weights without payloads and include the weight of the four bar linkage assemblies.

RESUPPLY MODULE WEIGHT BREAKDOWN

PRIMARY STRUCTURE	2485
SECONDARY STRUCTURE	865
AIR REVITALIZATION	316
GAS BOTTLES	550
FIRE DECT. AND REPRESS. SYS	57
ELECTRICAL	132
MLI INSTALLATION	101
AUDIO/VIDEO	20
CAUTION AND WARNING	25
BERTHING MECH ACTIVE ASSY.	415
EXTERNAL UMBILICAL ASSY.	105
RACKS AND MOUNTINGS	950
HAND AND FOOT RESTRAINTS	40
SUBTOTAL	6061
CONTINGENCY (15%)	910
TOTAL	6971

RMWEIGHTTBL

NASA

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nasa

6.1.5. DEVELOPMENT SCHEDULE

CDSF DEVELOPMENT SCHEDULE

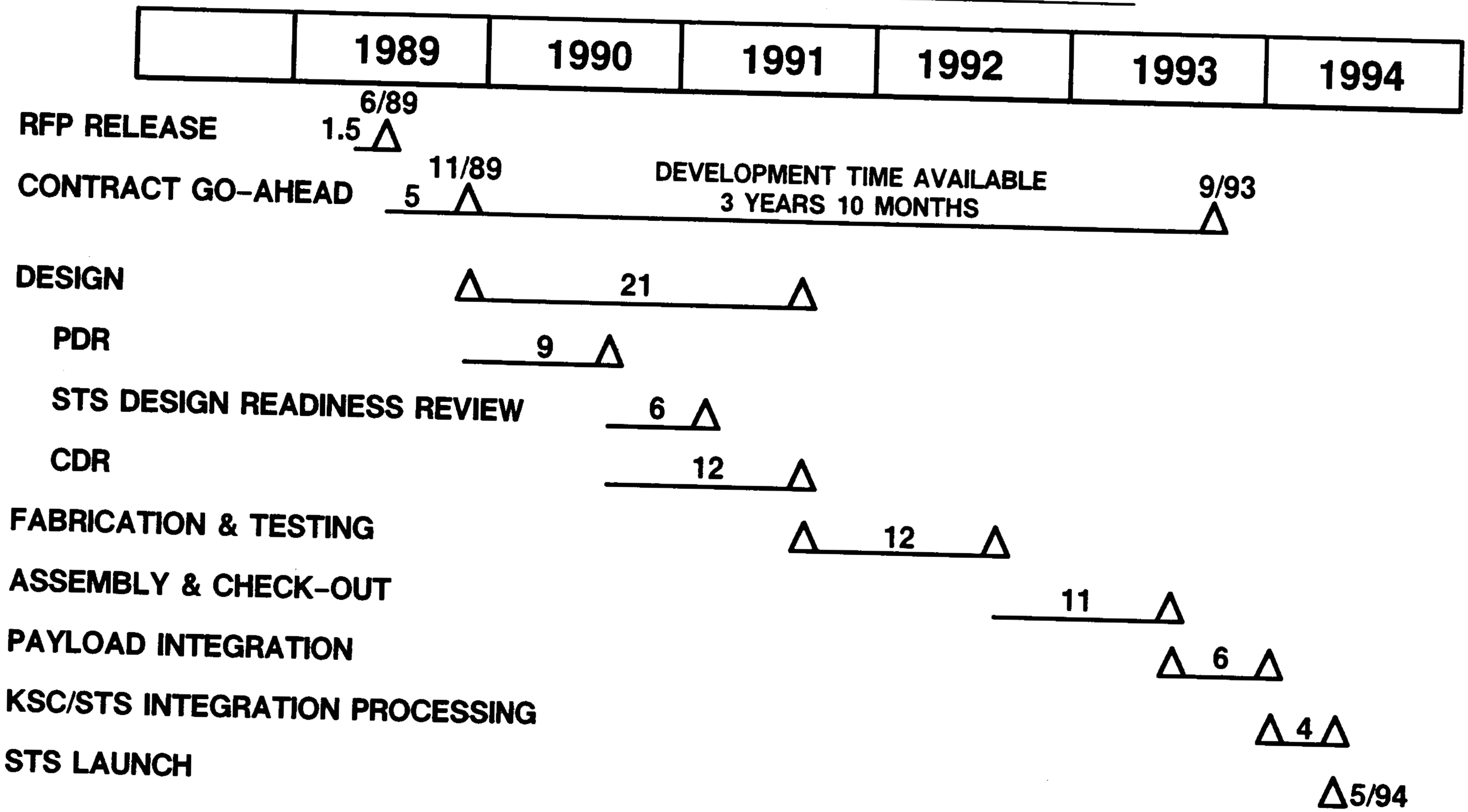
A CDSF development schedule was conceived based on a protoflight concept consistent with the cost analysis model approach documented in Volume II of this report. The cost estimation studies performed determined that the protoflight concept is the most cost effective approach for CDSF development. Another key consideration for cost effective CDSF development is the use of off the shelf space flight qualified hardware were possible and the selection of systems, and system components, that had a past tested and proven system design development heritage.

This development schedule assumed a June 1989 RFP release to proposers and a 5 month evaluation and contractor selection process as proclaimed by NASA Administrator Dr. James Fletcher commensurate with the February 11, 1988 announcement of the Presidential Directive on National Space Policy. As of this report writing NASA is prepared to initiate this procurement process evaluation with a Source Evaluation Board (SEB) activity at the Marshall Space Flight Center.

Based on the protoflight and proven hardware and design heritage approach considered, a 3 year 10 month development period is estimated for design, fabrication and testing, and assembly and check-out. Payload integration for candidate microgravity experiments selected for the initial deployment mission is estimated to take 6 months. It is assumed that these initial experiment hardware sets will have had previous SPACELAB installation compatibility. Four months is assumed for STS processing at Kennedy Space Center prior to launch.

The original intention of NASA for CDSF deployment focused on a first quarter 1993 deployment launch. However, it is estimated that a deployment launch would not be a conceivable consideration for no sooner than the fall of 1993 and assuming a November 1989 contractor go ahead is possible.

CDSF DEVELOPMENT SCHEDULE



- **DEVELOPMENT TIME EXCEEDS AVAILABLE TIME BY 8 MONTHS**

WORK AROUND – POSSIBLE TO SHORTEN THE DESIGN PROCESS BY ASSUMING THAT AT CONTRACT GO-AHEAD DEVELOPER HAS ESSENTIALLY COMPLETE PDR.

NASA

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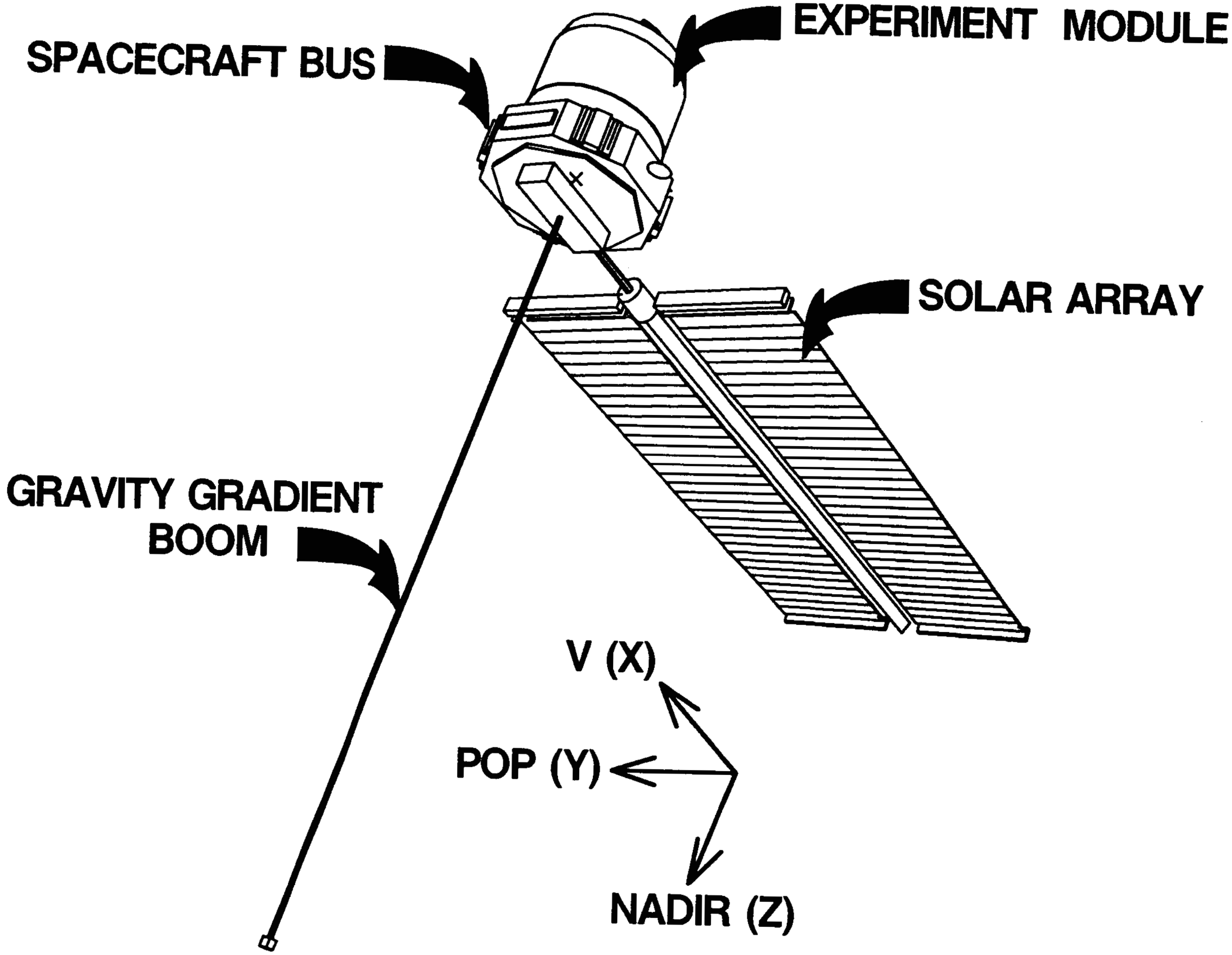
6.2. 20% EXPERIMENT ACCOMMODATION CONCEPT

CDSF CONCEPT #2 FREE FLYER CONFIGURATION

The CDSF reduced capability concept is described in this section. As previously stated, this concept has an experiment volume capacity of 80 cubic feet which is 20% of the capacity of the RFP reference configuration concept. The reduced capacity concept will be defined as concept #2 or the "20% concept" for purposes of description in this section.

The CDSF #2 free flyer configuration is made up of several components which include an experiment module, a spacecraft bus and a gravity gradient boom. The experiment module is a 12.5' diameter 12' long pressurized cylinder that accommodates the experiment hardware. Attached to the experiment module is a spacecraft bus which houses the avionics, propulsion and power subsystems. A single feathered solar array is deployed out of the spacecraft bus along the flight path direction trailing the experiment module. The gravity gradient boom is attached to the top of the experiment module and points towards the Earth in the free flyer mode. The CDSF free flyer has a gravity gradient stable orbital flight attitude where nadir is aligned along the longitudinal axis of the experiment module and the gravity gradient boom. The velocity vector is aligned with the longitudinal axis of the feathered solar array.

CDSF CONCEPT #2 FREE FLYER CONFIGURATION

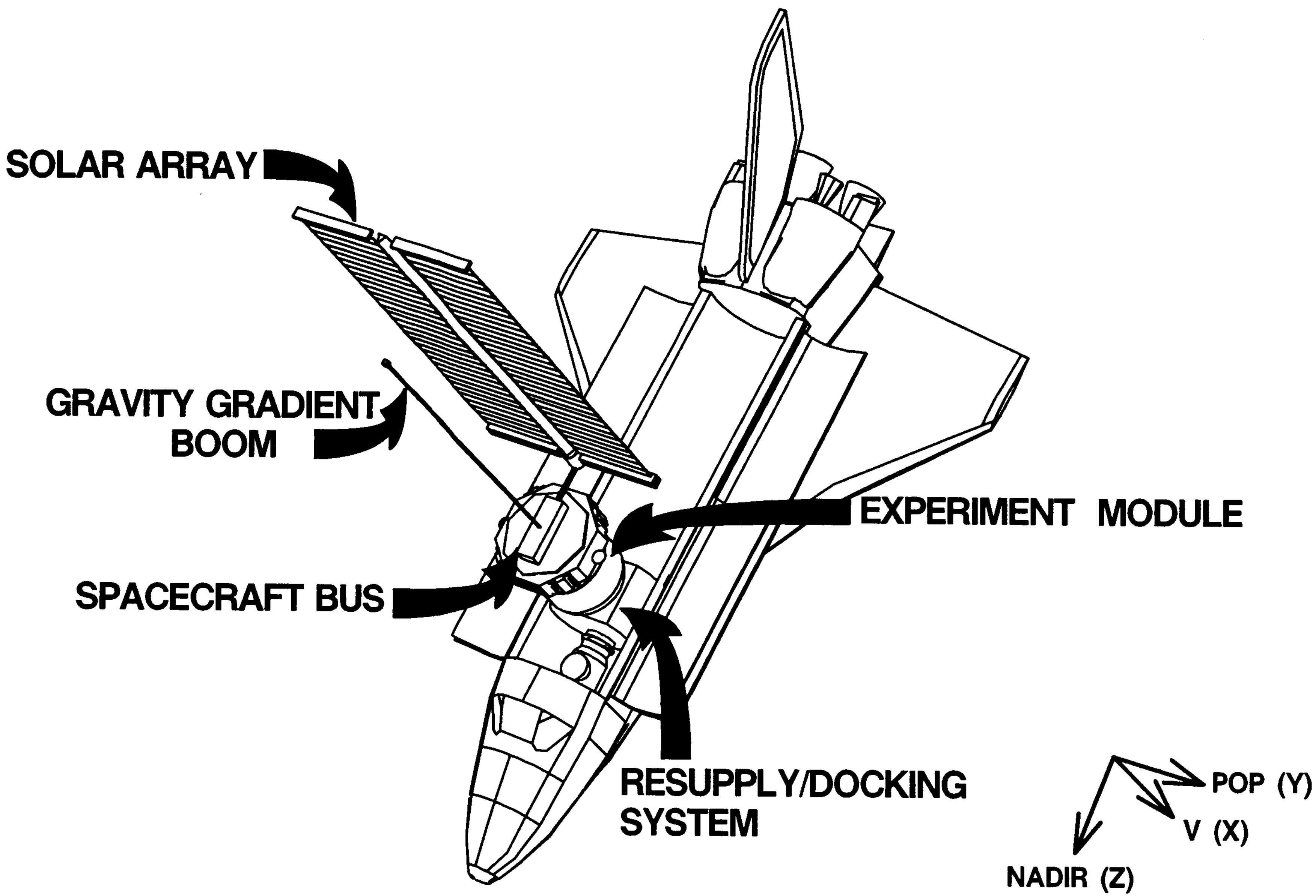


FREE20

CDSF CONCEPT #2 MATED CONFIGURATION

The CDSF #2 mated configuration is achieved by berthing the CDSF with the orbiter RMS to the orbiter docking system. Prior to berthing, the CDSF solar arrays must be rotated to provide proper clearance, stability and power characteristics. The mated configuration is oriented to a gravity gradient stable flight mode attitude with the nose of the orbiter pointing towards the Earth, the bottom of the orbiter into the flight path and the orbiter wings perpendicular to the orbit plane.

CDSF CONCEPT #2 MATED CONFIGURATION



MATE20

CDSF CONCEPT #2 WEIGHT ALLOCATION SUMMARY

Subsystems in the CDSF were analyzed on a weights basis to establish weight allocations that provide maximum experiment weight based on STS OV-102 lift capability could be determined. The largest weight definition is the spacecraft bus followed by the structural elements of the CDSF and the power system. Taking into account the weight of the docking system, retention devices, associated support equipment and payload specialists; OV-102 could launch the CDSF configuration with about 2000 pounds of experiments to a deployment altitude of 175 n.mi. This represents an experiment rack outfitting of about 100% assuming a rack density of 25 pounds of experiment per cubic foot of rack space.

CDSF CONCEPT #2 WEIGHT ALLOCATION SUMMARY

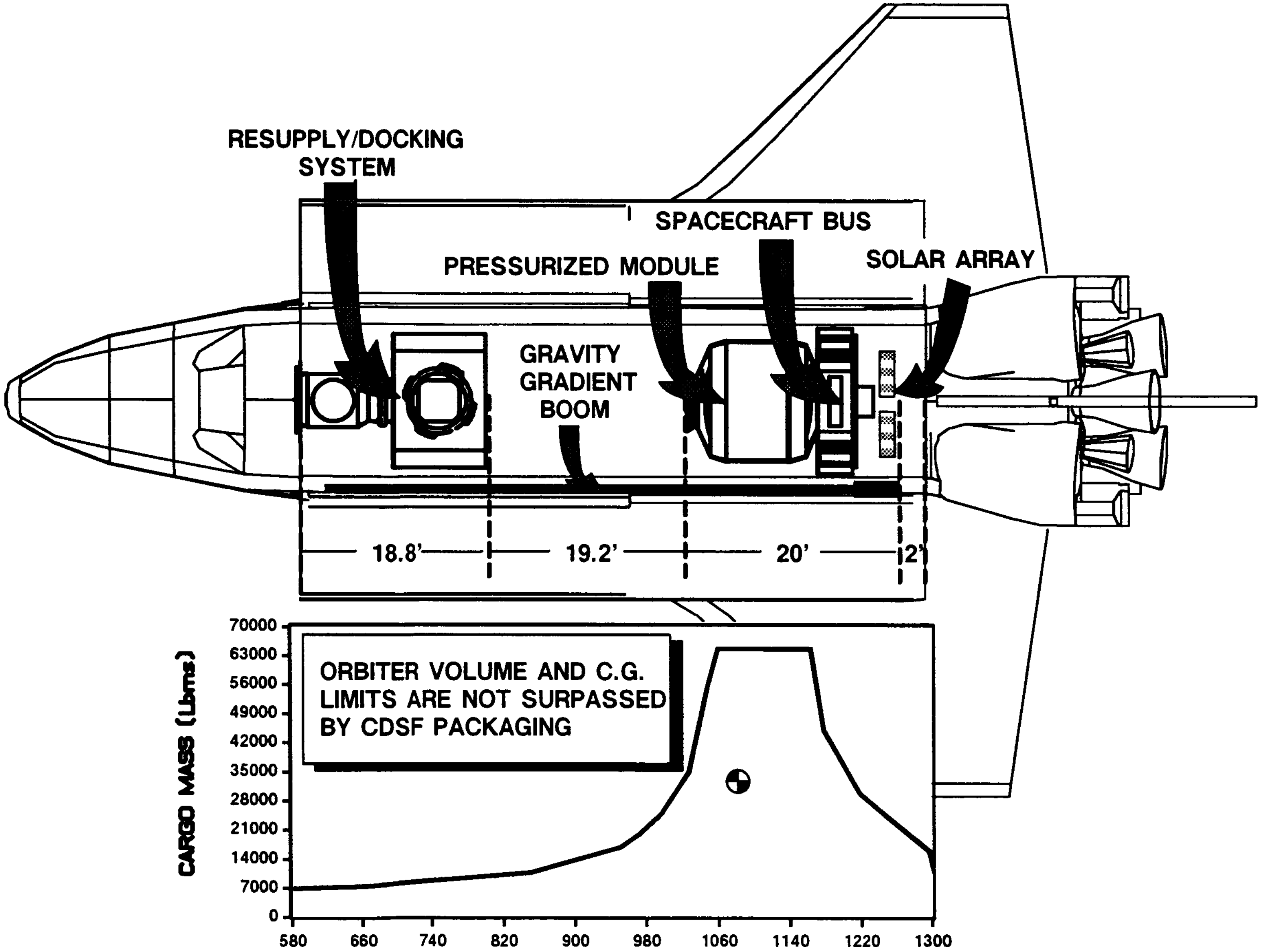
ITEM DESCRIPTION	WEIGHT (LBS)
EXPERIMENT MODULE STRUCTURE	7920
- SCIENCE DATA SYSTEM	80
- THERMAL	940
- ENVIRONMENTAL CONTROL	1860 *
4 KW POWER AUGMENTATION MODULE	3450
SPACECRAFT BUS(inc. 1350 lbm fuel)	9000
EXPERIMENTS	2000
SUBTOTAL	25250
RESUPPLY/DOCKING SYSTEM	7390
P/L RETENTION	2200
MISC. ASE	300
P/L SPECIALIST	900
MARGIN	90
TOTAL LAUNCH WEIGHT TO 175 NMI	36130

**WEIGHT FOR A 3 YEAR MISSION, USE 2370 LBS FOR 5 YEAR MISSION*

CDSF CONCEPT #2 CARGO BAY PACKAGING

An orbiter packaging analysis was performed for this CDSF configuration. The orbiter cargo bay is 60 feet long and has a dynamic envelope that is 14.5 feet in diameter. All cargo elements must have 2 feet of space between them to allow for RMS runaway and the combined cargo center of gravity must fall within the operational limits specified by the STS. The resupply/docking system (explained in detail later on in this report) is attached to the forward bulkhead and extends 18.8 feet into the cargo bay with a 19.2 foot space between it and the experiment module. The experiment module is 12 feet in length and 12.5 feet in diameter. Attached to the experiment module is the spacecraft bus which takes up 8 feet of the cargo bay with the solar array in its stowed position. Two feet of empty space remains aft of the spacecraft bus for aft bulkhead clearance. The rigid gravity gradient boom is stowed in the unused orbiter arm sill. Using the latest STS provided cargo mass center of gravity information, it was shown that the CDSF packaging did not surpass cargo C.G. limits.

CDSF CONCEPT #2 CARGO BAY PACKAGING



X-AXIS C.G. ENVELOPE FOR STS CARGO

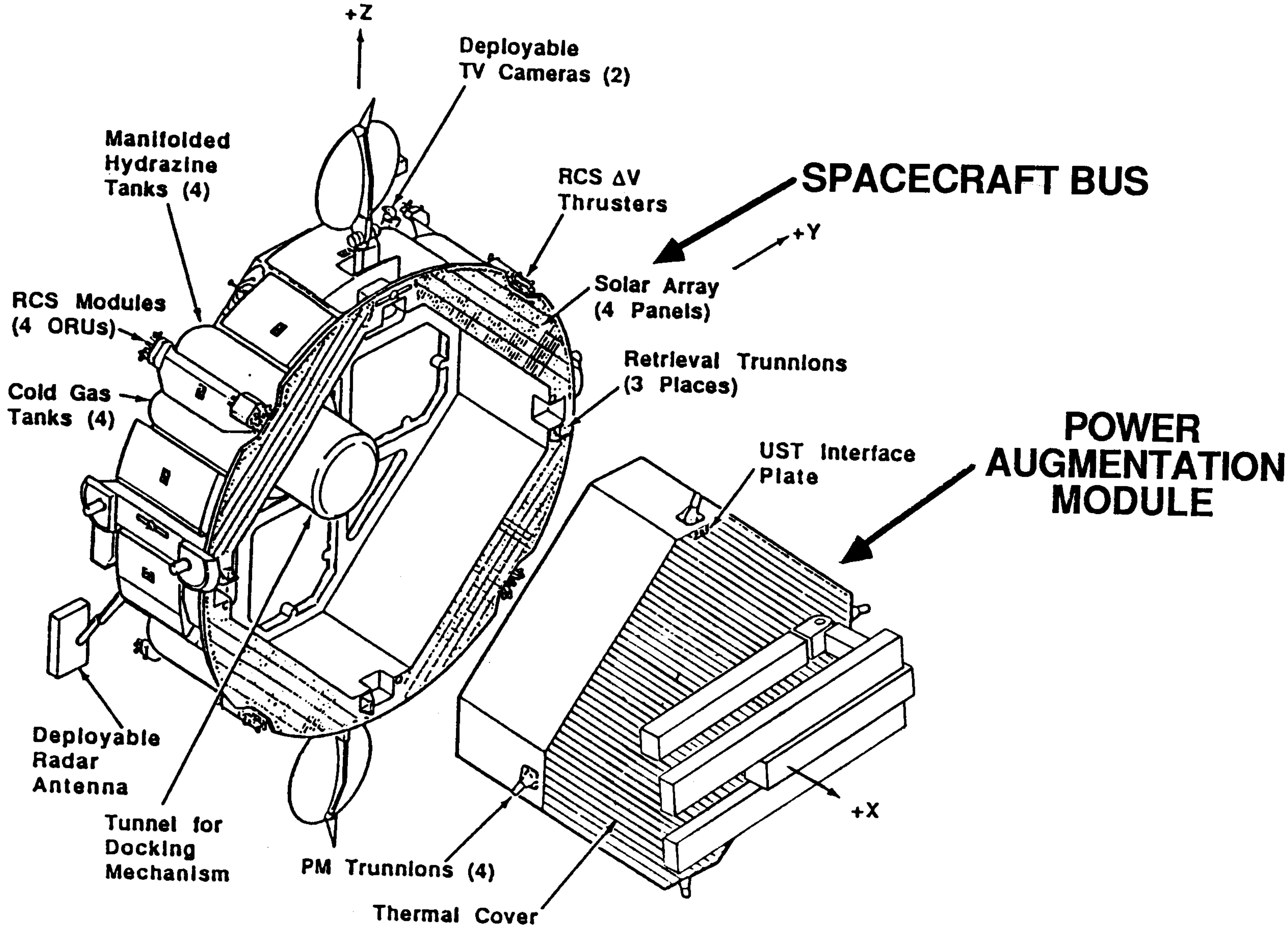
PACK20

20% CDSF SPACECRAFT BUS CONCEPT

The Spacecraft Bus is proposed to be an Orbital Maneuvering Vehicle (OMV) currently being developed by TRW Space & Technology Group for MSFC. It is proposed to use the OMV Short Range Vehicle as defined at its PDR August 22, 1988. Propulsion, communications and some housekeeping power are to be supplied to the CDSF from the OMV.

Because of the large power requirements for the CDSF, a Power Augmentation Module (PAM) is required. It is proposed to use the volume in the OMV allocated for the Propulsion Module for the CDSF PAM. It is anticipated that the design of the structure for the PAM would be very similar to the design of the structure for the Propulsion Module. Mounted on the external face of the PAM is a 3080 square foot solar array with its deployment and beta tracking mechanisms.

20% CDSF SPACECRAFT CONCEPT



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6.2.1. EXPERIMENT MODULE LAYOUT AND STRUCTURAL DESIGN

20% CDSF EXPERIMENT MODULE DIMENSIONS

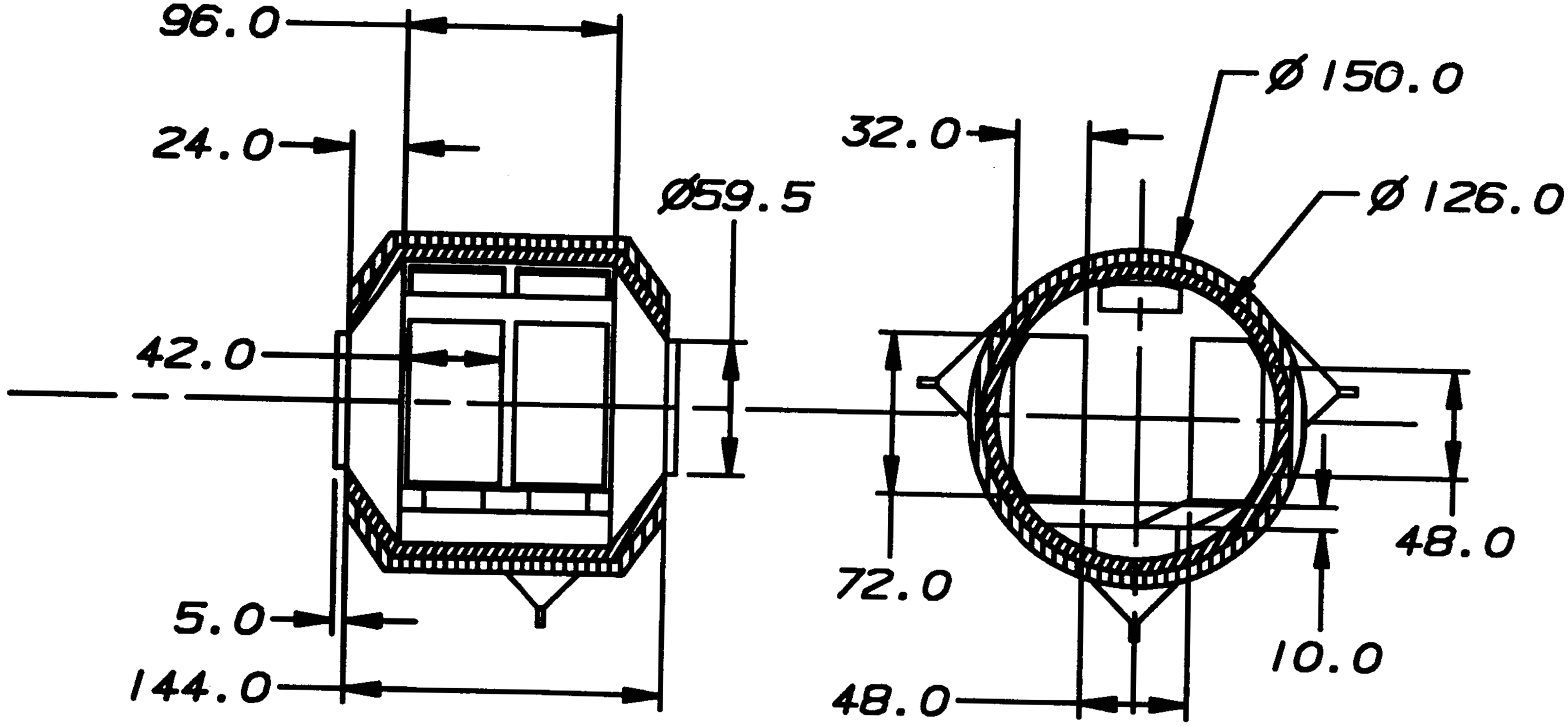
The Experiment Module (EM) contains two CDSF Experiment Racks, Data Collection and Storage Subsystem to support the experiments, life support systems, thermal control systems, and the necessary structure and mechanisms. The EM has one docking port for berthing with the Resupply/Docking Module.

The EM is a cylinder with 25 degree conical ends. Overall length of the EM is 12 feet with an external diameter of 12.5 feet and an internal diameter of 10.5 feet.

The shell of the EM consists of two layers. (1) The internal layer, creates the pressurized volume and contains the load bearing structure with thermal insulation. (2) The external layer, which serves as a micrometeoroid and debris shield and contains the thermal radiator.

Located in the end of the cylinder is a 46 in. square hatch to accommodate the Experiment Racks.

CDSF CONCEPT #2 EXPERIMENT MODULE AND RACK DIMENSIONS
(DIMENSIONS IN INCHES)



CDSF2DIM

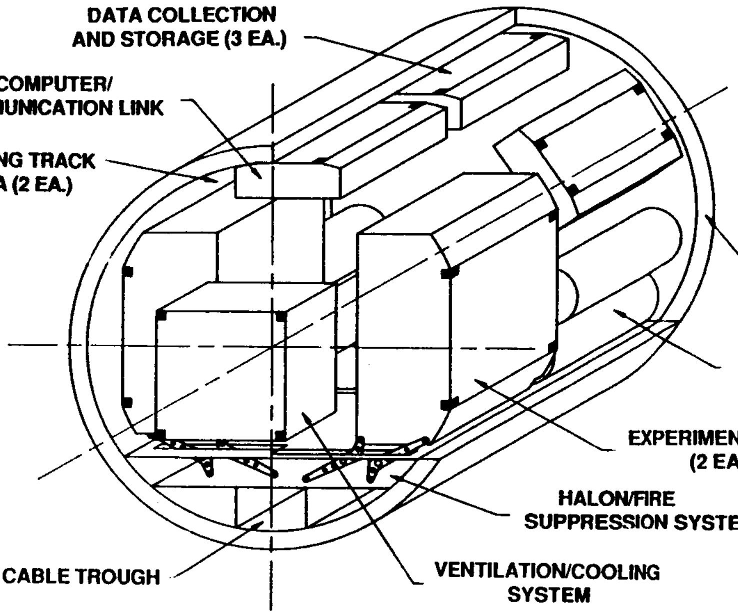
20% CDSF EXPERIMENT MODULE (EM) LAYOUT

Internal to the EM are the Experiment Racks which are attached to the EM structure at four points and through a four bar linkage system. To obtain access to the pressure shell behind the rack or to remove a rack an astronaut would release the four point latch system and rotate the rack into the isle. To remove the rack it would be then released from the four bar link system rotated 90 degrees and maneuvered through the access hatch.

All internal components are conceived to be easily replaceable on orbit.

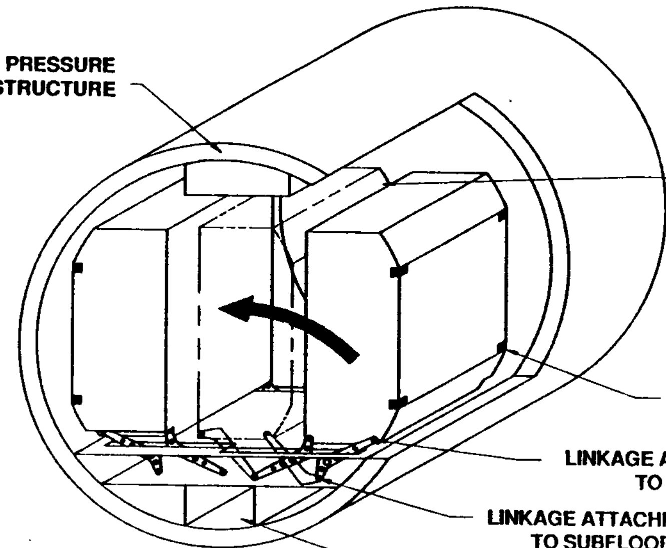
20% CDSF CONCEPT EXPERIMENT MODULE

INTERNAL COMPONENT ARRANGEMENT



- MODULE DRY WEIGHT = 9820 LBS
- PRESSURIZED VOLUME = 790 FT^3

4-BAR RACK LINKAGE CONCEPT



2 DOUBLE EXPERIMENT RACKS

EXPERIMENT VOLUME = 80 FT^3

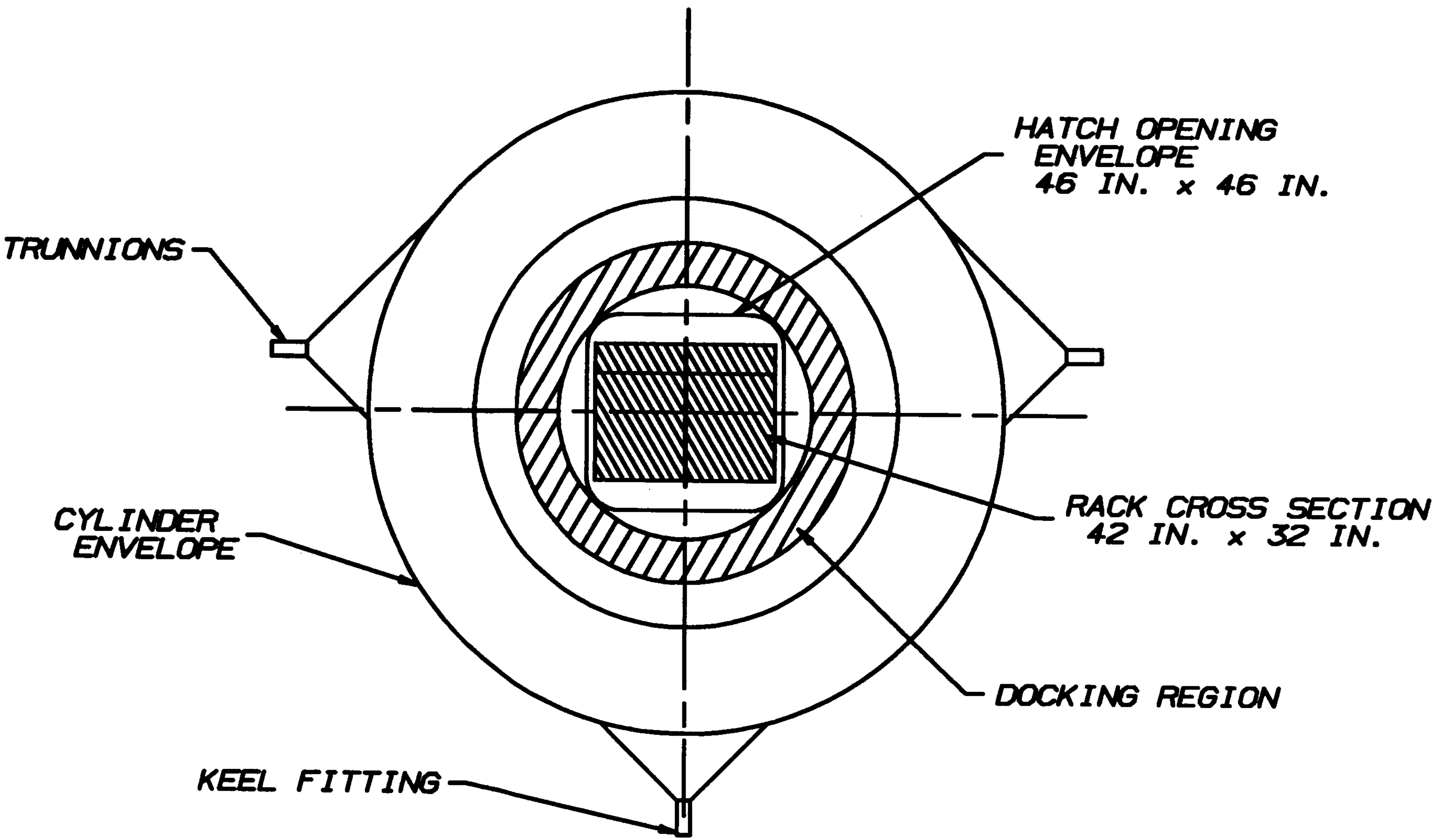
EXPERIMENT WEIGHT = 2000 LBS

MN/C10

20% CDSF CONCEPT RACK REMOVAL CLEARANCE

The hatch in the EM is shown for rack removal operation to allow the CDSF Experiment Racks to be maneuvered through the opening. A 46" by 46" hatch opening envelope is shown to accommodate passing through a 42" by 32" experiment rack cross section.

CDSF CONCEPT #2 RACK REMOVAL CLEARANCE

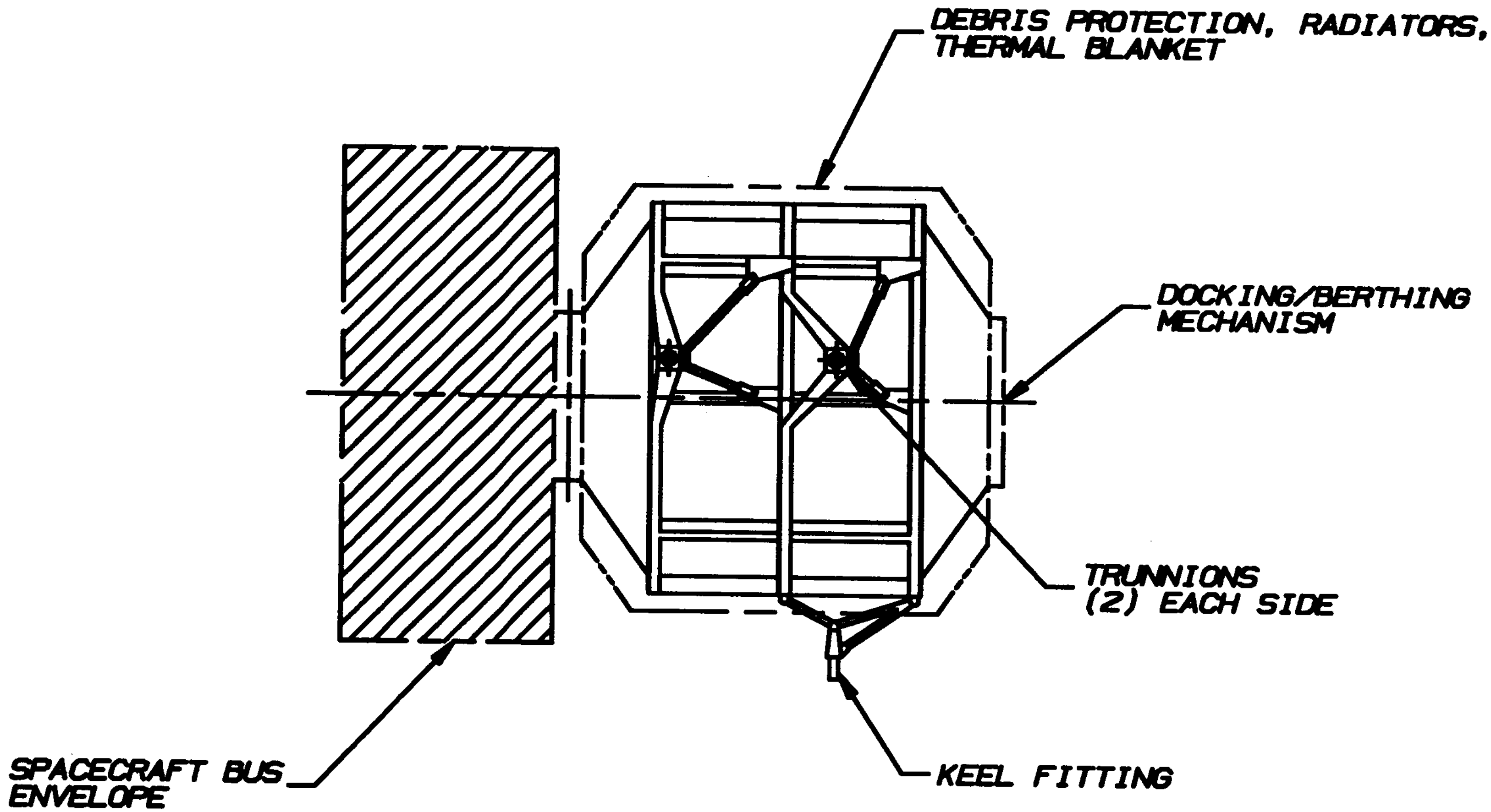


CDSF2RRC

20% CDSF CONCEPT PRIMARY PRESSURE VESSEL STRUCTURE

The structure subsystem for the experiment module provides the structural support for all other subsystems, the distribution of loads, attachment to the STS for launch, pressure integrity, and impact protection. Trunnions and keel fitting design is dictated by STS requirements.

CDSF CONCEPT #2 PRIMARY PRESSURE VESSEL FRAMEWORK

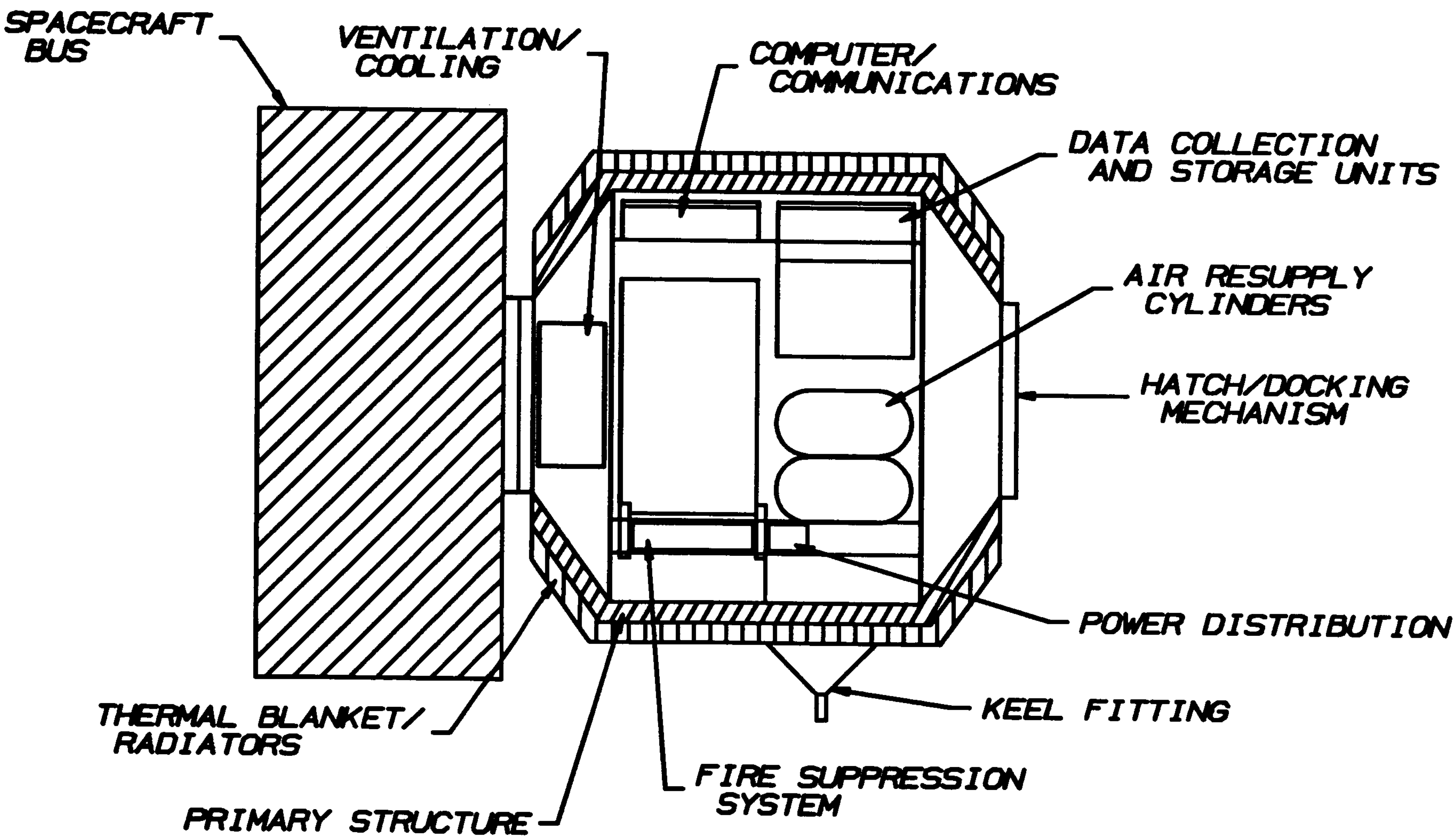


CDSF#2PVF

20% CDSF CONCEPT LONGITUDINAL CROSS SECTION

This layout view depicts the internal accommodation locations for subsystem components in the experiment module. The primary pressure vessel structure and outer protective structure layers are shown. The outer structure also contains the thermal radiators.

CDSF CONCEPT #2 LONGITUDINAL CROSS SECTION

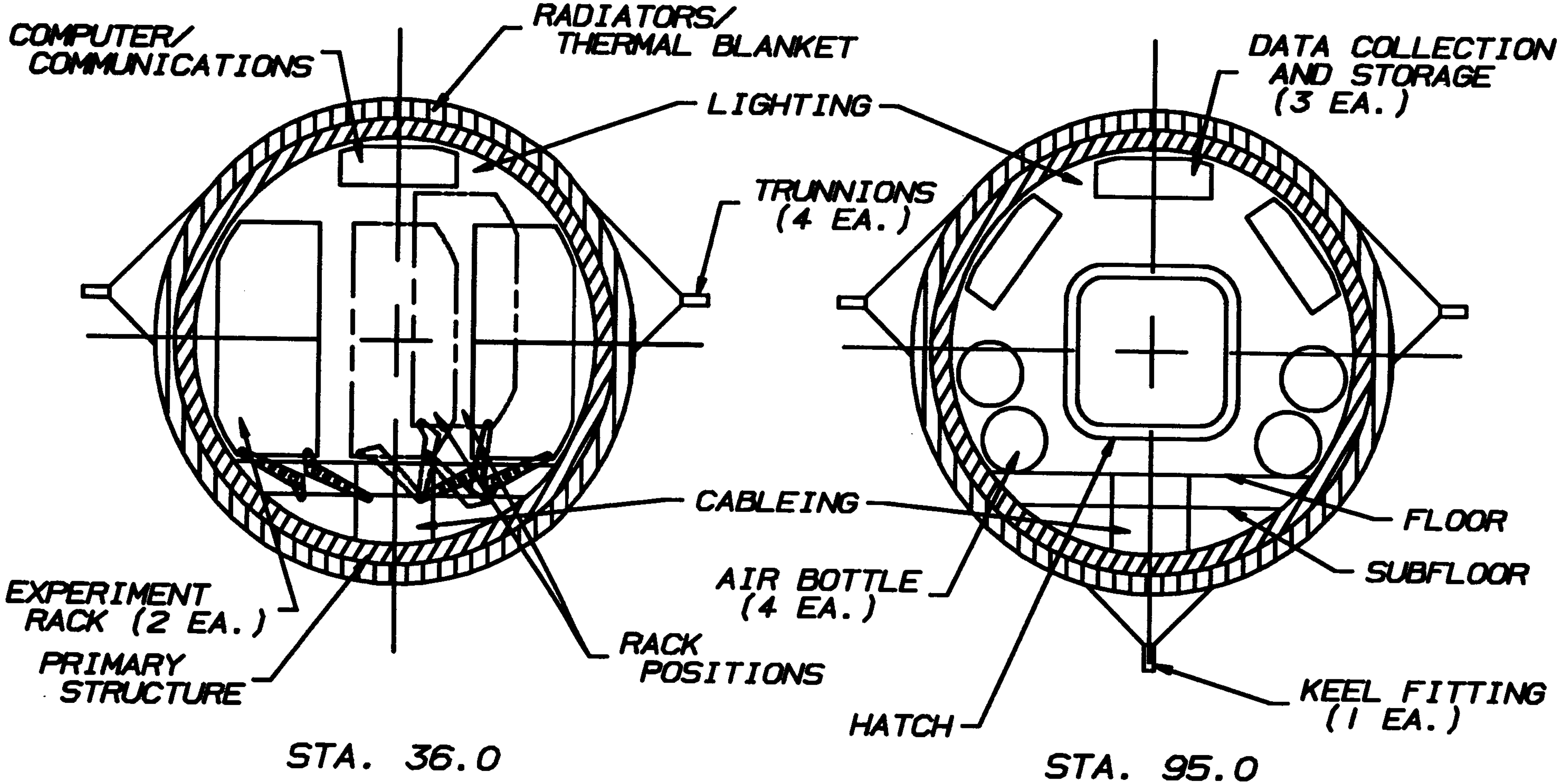


CDSF2LCS

20% CDSF CONCEPT TRANSVERSE CROSS SECTION

This drawing depicts the experiment rack locations, rack removal operation movement and clearances internal to the experiment module. Internal lighting and electrical cable raceways are shown beneath the module floor.

CDSF CONCEPT #2 TRANSVERSE CROSS SECTIONAL VIEWS

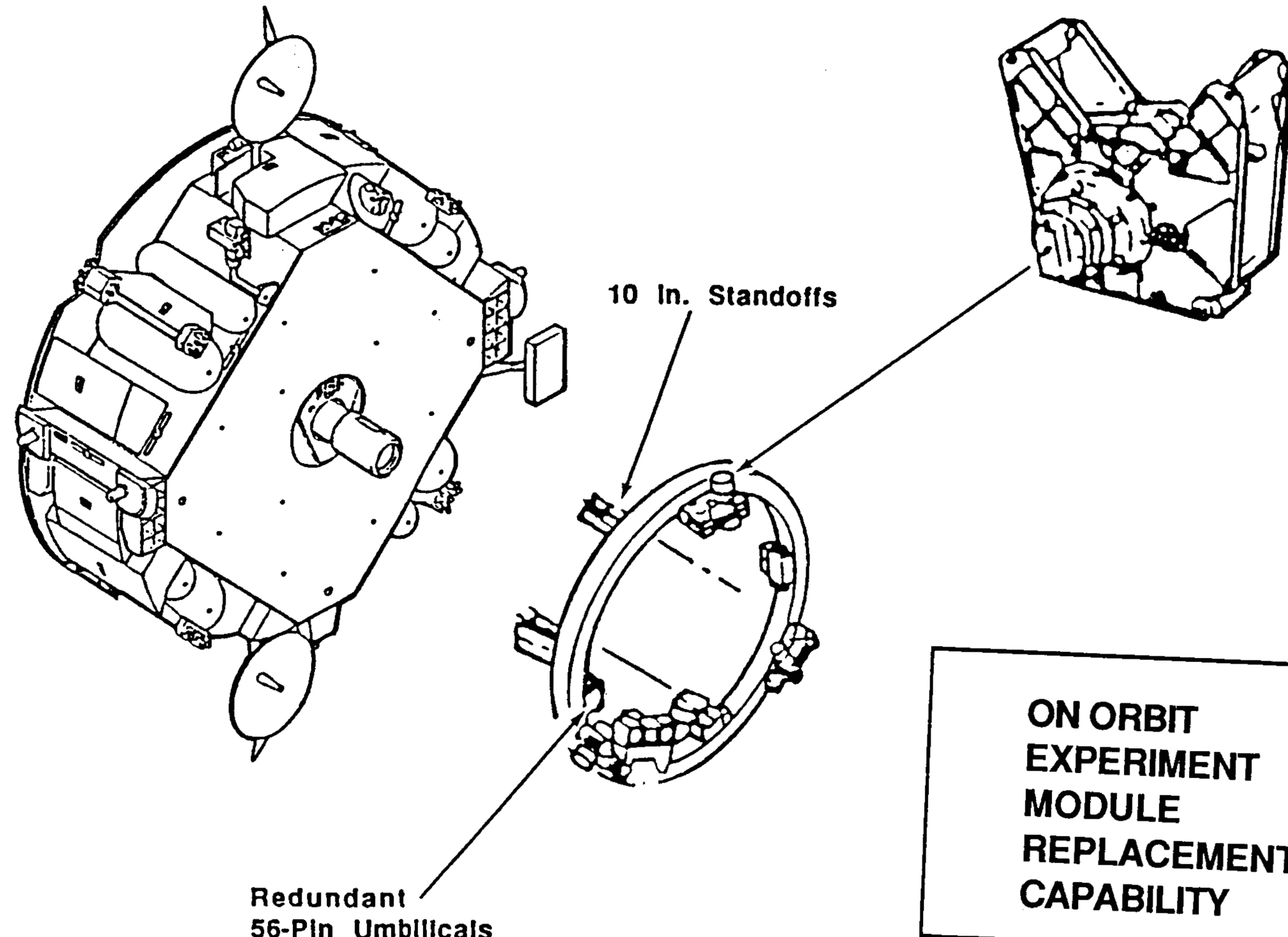


CDSF2TCSV

THREE POINT DOCKING MECHANISM INTERFACE

Located in the end of the experiment module (EM) opposite the access hatch are three attachment points compatible with the three point docking mechanism in the spacecraft bus (SB). Although it is not required it is proposed that the EM and SB be attached when launched and deployed from the STS. The three point docking mechanism will allow either the EM or SB to be exchanged on orbit.

THREE POINT DOCKING MECHANISM INTERFACE



ON ORBIT
EXPERIMENT
MODULE
REPLACEMENT
CAPABILITY

20% CDSF CONCEPT STRUCTURE WEIGHT BREAKDOWN

The total structure weight breakdown of the experiment module for the 20% CDSF concept (#2) is listed. Hatch and mechanisms weight include the 3 point attachment mechanism weight.

20% CDSF EXPERIMENT MODULE STRUCTURE WEIGHT

PRIMARY STRUCTURE	2200
SECONDARY STRUCTURE	500
HATCH AND MECHANISMS	2000
DOUBLE RACKS (2)	950
STORAGE LOCKERS (5)	150
GRAVITY GRADIENT BOOM	1000
MAN SYSTEMS	85
SUBTOTAL	6885
CONTINGENCY (15%)	1033
TOTAL	7918

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6.2.1.1 ENVIRONMENTAL CONTROL SYSTEM

CDSF CONCEPTUAL DESIGN REQUIREMENTS AND ASSUMPTIONS

Several major requirements and assumptions were considered in the design of the CDSF. All tanks and systems were sized such that the CDSF could survive for three years without servicing to prevent the possibility of facility loss in case of STS down time. The CDSF will be repressurized to 14.7 psia per shuttle visit and must maintain 14.7 psia in the free flyer mode with a leak rate of 0.5 lbm/day. Crew-tended operations will occur only when the CDSF is attached to the shuttle which will handle all life support requirements. One crew member can work in the CDSF for up to 25 days for EDO missions.

CONCEPT 2 ENVIRONMENTAL CONTROL DESIGN REQUIREMENTS AND ASSUMPTIONS

- CDSF three year orbital life without servicing
- Internal pressurized volume of 885 ft^3
- Cabin atmosphere at 14.7 psia
- One repressurization required per shuttle visit
- CDSF leak rate of 0.5 lb/day
- Maximum of one crew member can work in CDSF
- Life support requirements supplied entirely by shuttle system

CDSF ENVIRONMENT CONTROL DESIGN DESCRIPTION

A description of the CDSF environment control system is given for atmosphere control and supply, trace contaminant control, ventilation, and fire detection and suppression. The CDSF atmosphere is supplied by oxygen and nitrogen in high pressure storage. Trace contaminant control is accomplished with a monitoring system and catalytic oxidation and filters. The CDSF ventilation system connects into the Orbiter's air revitalization system and can be operated in a free flyer mode to remove contaminants. The CDSF fire detection and suppression system includes detection and pyro control subassemblies, a fire extinguisher subassembly, a portable fire extinguisher, and one emergency breathing pack.

CONCEPT 2 ENVIRONMENTAL CONTROL DESIGN DESCRIPTION

Atmosphere control and supply
- High pressure storage of oxygen and nitrogen
- Atmosphere monitoring and control system

Trace contaminant control
- Monitoring system
- Catalytic oxidation and filters

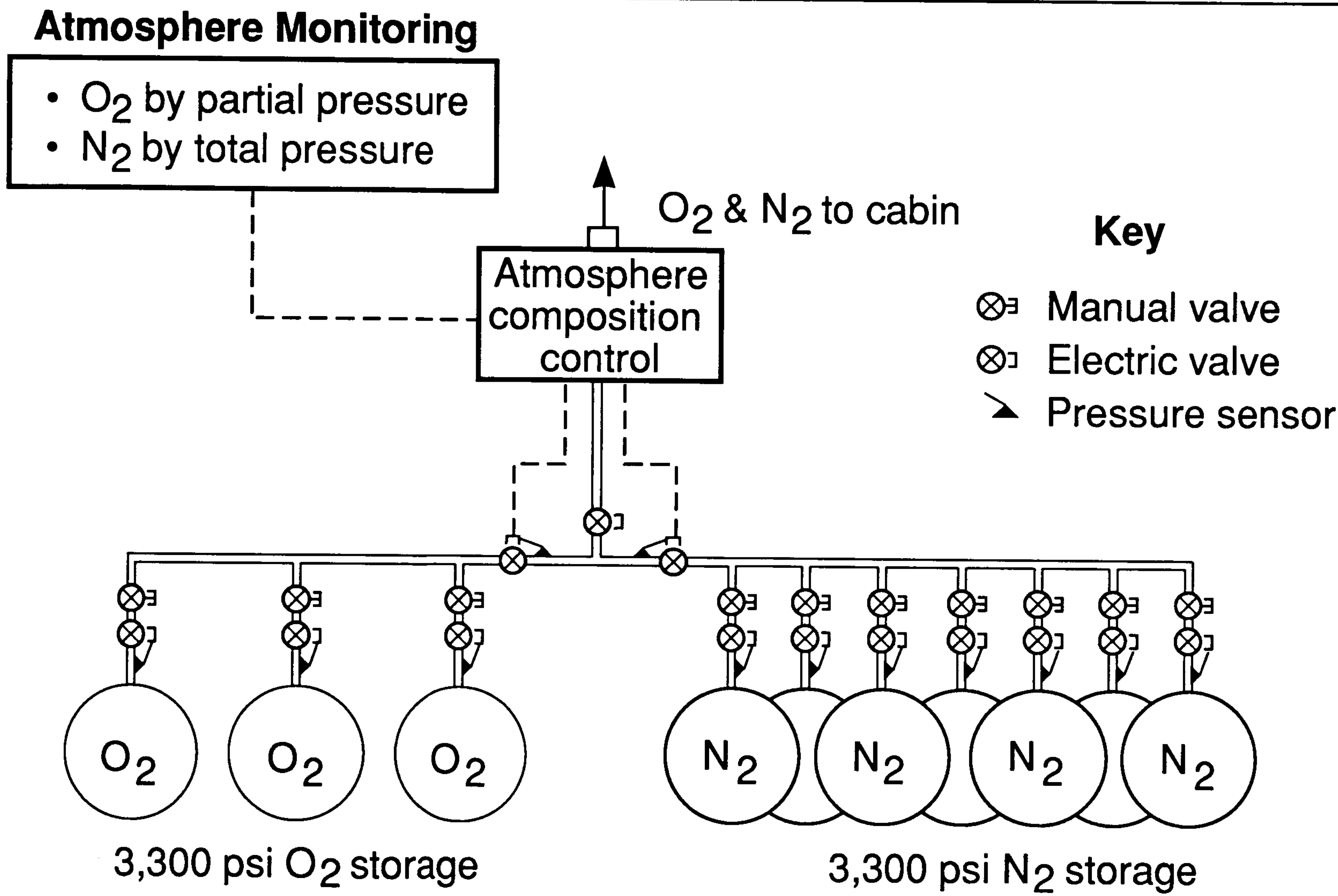
Ventilation
- Connects into shuttle's air revitalization system
- Includes ventilation ducting, outlet ducts, intake ducts, and cabin air fan
- Can be run in free flyer mode to remove contaminants

Fire detection and suppression
- Detection and pyro control subassemblies
- Fire extinguisher subassembly
- 1 portable fire extinguisher
- 1 emergency breathing pack

CONCEPT 2 ATMOSPHERE CONTROL AND SUPPLY SCHEMATIC

The atmosphere control and supply (ACS) system is designed to maintain the CDSF internal pressure at 14.7 PSIA with an 0_2 partial pressure of 3.2 PSIA and an N_2 partial pressure of 11.5 PSIA. The oxygen and nitrogen are stored at 3,300 psi in shuttle carbon wound filament tanks. The ACS contains sufficient gases to make up a CDSF leak rate of 0.5 lb/day for missions of 3 years and to repressurize the cabin once per shuttle visit. This system operates only in the free flyer mode. While the CDSF is docked with the shuttle, the shuttle will supply all makeup gases.

CONCEPT 2 ATMOSPHERE CONTROL AND SUPPLY SCHEMATIC

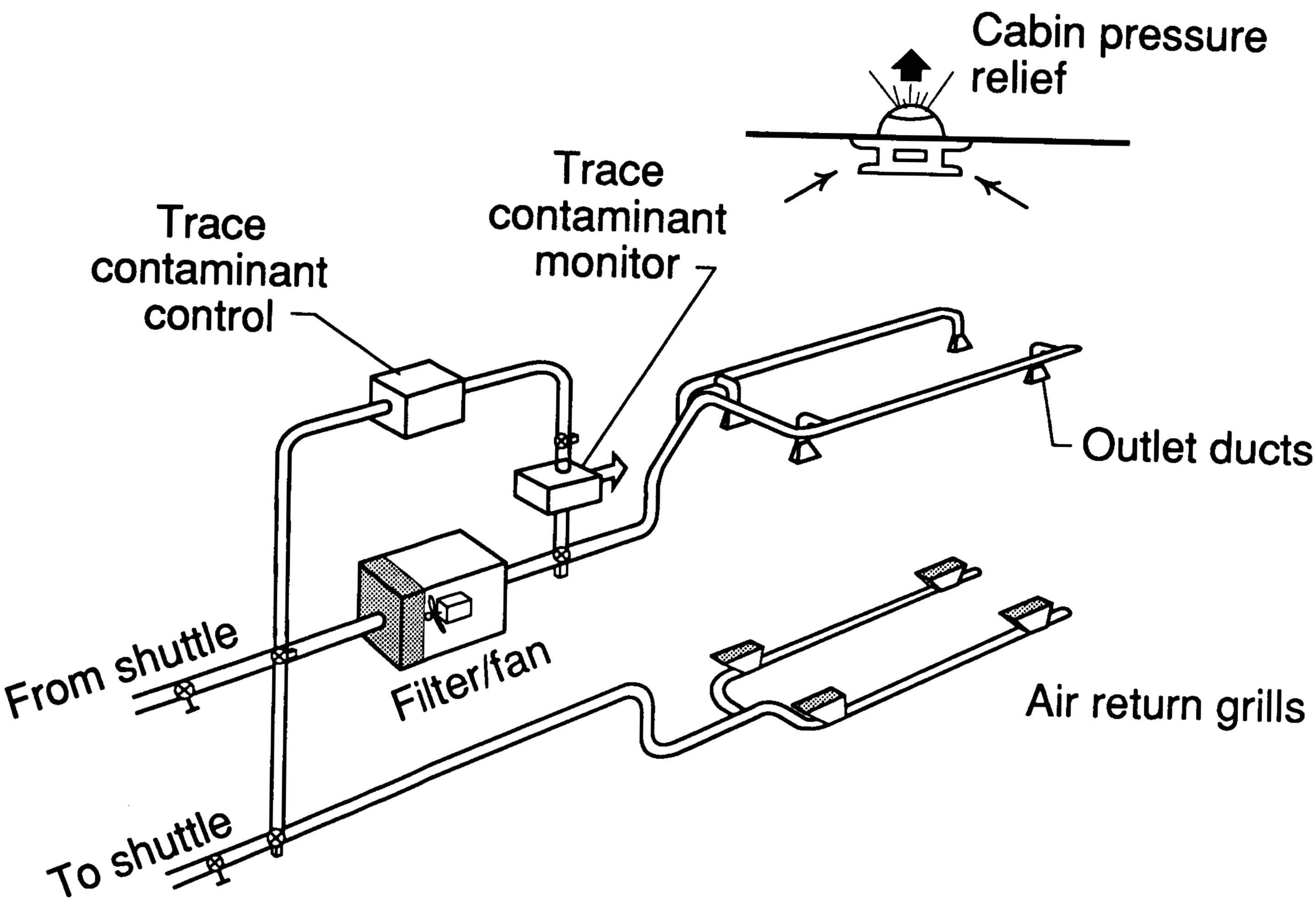


Note: 5 year mission requires an additional O_2 tank and 5 N_2 tanks resupply equals 180 days or 3 years

CONCEPT 2 VENTILATION AND TRACE CONTAMINANT SCHEMATIC

CDSF concept 2 contains the interfaces required to connect to the Space Shuttle Orbiter air revitalization system. While the CDSF is docked. the orbiter environmental control and life support systems remove carbon dioxide, humidity, and sensible heat. The shuttle life support systems also supply metabolic oxygen, cabin leakage makeup and airlock gas makeup. In the free flyer mode, the fan shown in the schematic can be operated to enable trace contaminant monitoring and removal by catalytic oxygen and filters.

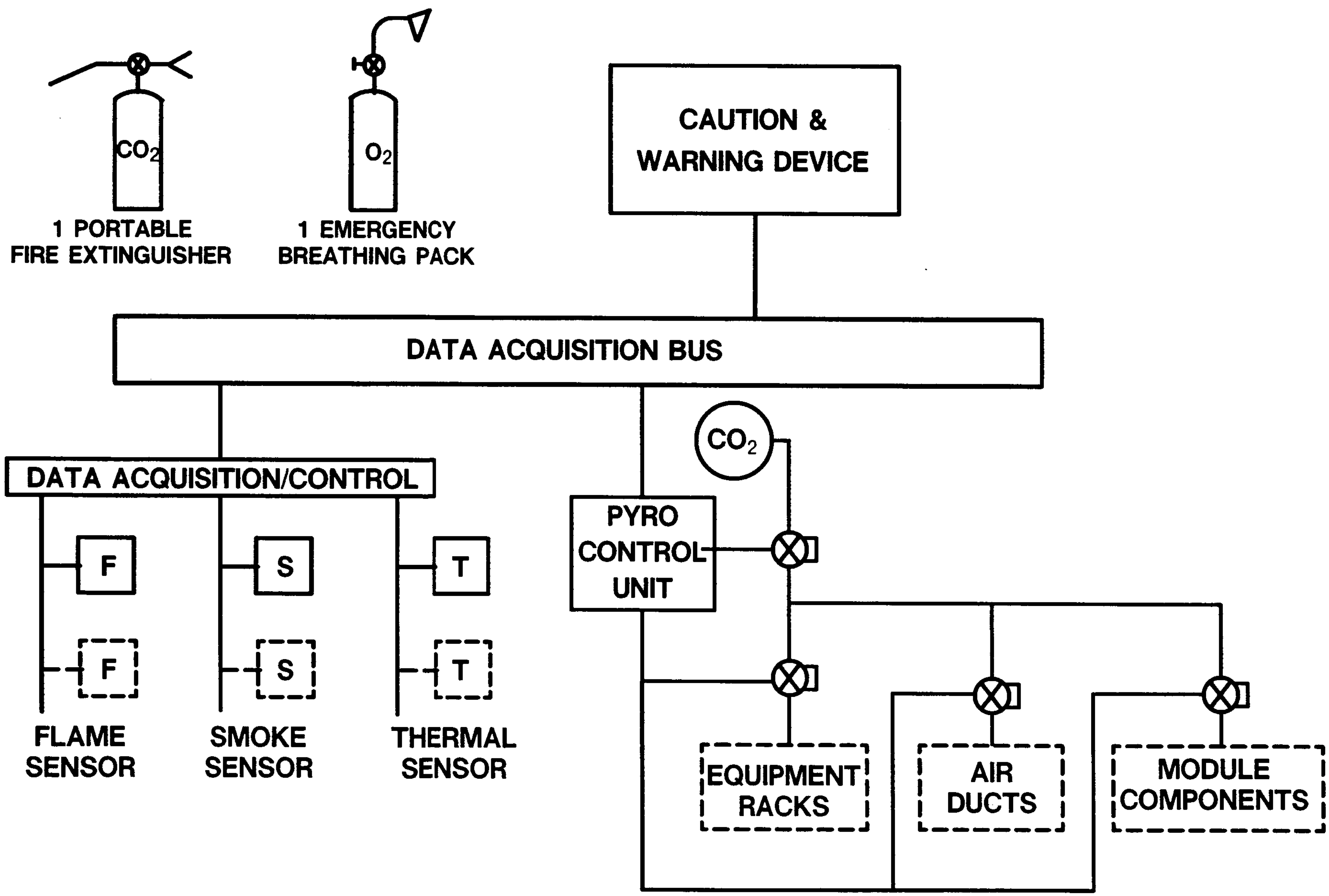
CONCEPT 2 VENTILATION AND TRACE CONTAMINANT SCHEMATIC



CONCEPT #2 FIRE DETECTION AND SUPPRESSION SYSTEM

The fire detection system contains sensors that identify flames, smoke or heat in the equipment racks, air ducts, and module components. The signals from the sensors automatically activate the suppression unit which applies CO_2 to control the fire. A portable fire extinguisher is included as well as one emergency breathing pack for crew safety.

CDSF #2 FIRE DETECTION AND SUPPRESSION SYSTEM



CDSF FIRE DETECTION & SUPPRESSION SYSTEM WEIGHT BREAKDOWN

A weight breakdown for the fire detection and suppression system is presented.

CDSF FIRE DETECTION & SUPPRESSION WET WEIGHT

	WET WEIGHT (LBS)	
DETECTION		
Fire Detection Subassembly	16.0	
Pyro Control Box Subassembly	6.8	
SUPPRESSION		
Fire Extinguisher Subassembly	17.0	[13 LBS CO_2]
Portable Fire Extinguisher	6.9	[5 LBS CO_2]
1 Emergency Breathing Pack	17.6	[1 LBS O_2]
Plumbing	8.0	
Valves	5.0	
Controller Assembly	10.0	
SUBTOTAL	87.3	[18 LBS CO_2] [1 LBS O_2]
CONTINGENCY (15%)	13.0	
TOTAL	100.4	

DRY WEIGHT = 87.3 - 19.0 = 68.3 LBS

CONCEPT 2 ENVIRONMENTAL CONTROL SYSTEM SUMMARY

The concept 2 configuration has an internal pressurized volume of 885 ft^3. The ventilation system and fire detection and suppression system estimates are sized for this volume. The atmosphere control and supply system accounts for over 70% of the total environmental control system weight because its size is driven by the 0.5 lb / day leak rate assumption. System weights are shown here for both a 3 year operational option and a 5 year operational option for CDSF configuration trade-off purposes. The 3 year option was chosen because of its much smaller weight and volume.

CONCEPT 2 ENVIRONMENTAL CONTROL SYSTEM SUMMARY

Item	Flight Unit Wet Weight (lb)	Flight Unit Dry Weight (lb)	Flight Unit Volume (ft^3)	Resupply						Power (kW)
				180 Days		3 Years		5 Years		
				Weight (lb)	Volume (ft^3)	Weight (lb)	Volume (ft^3)	Weight (lb)	Volume (ft^3)	
Atmosphere supply	1299 * (2047) **	617 * (1000) **	52.5 * (83.1) **	322	14.1	1162	47.0	1860	75.2	0
Atmosphere Control & Monitoring	60	60	3.5	4	0.1	12	0.3	18	0.5	0.050
Trace Contaminant Control & Monitoring	127	127	4.1	7	0.2	42	1.2	70	2.0	0.24
Fire Detection & Suppression	87	68	1.7	2	0.1	11	0.2	19	0.3	0.067
Ventilation	45	45	7.6	0	0	5	0.5	5	0.5	0.043
Total	1618 * (2366) **	917 * (1300) **	69.4 * (100.0) **	335	14.5	1232	49.2	1972	78.5	0.400

* Initial Flight Unit weight and volume for 3 year mission

** Initial Flight Unit weight and volume for 5 year mission

CDSF ENVIRONMENTAL CONTROL SYSTEM WEIGHT BREAKDOWN

A weight breakdown for the environmental control system is presented. Note that the heaviest part of the system is the atmosphere supply. The large weight is driven by the combination of two factors. The first factor is the experiment module leakage rate of .5 pounds of air per day. The second factor is the requirement to maintain nominal atmosphere pressure for three years without orbiter resupply. Reduction of either one of these factors could significantly reduce the weight of the environmental control system.

CDSF #2 ENVIRONMENTAL CONTROL SYSTEM WEIGHT BREAKDOWN

	WET	DRY
ATMOSPHERE SUPPLY	1299	617
ATMOSPHERE CONTROL & MONITORING	60	60
TRACE CONTAMINANT CONTL & MONITORING	127	127
FIRE DETECTION & SUPPRESSION	87	68
VENTILATION	45	45
SUBTOTAL	1618	917
CONTINGENCY (15%)	243	138
TOTAL	1861	1055

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6.2.1.2. THERMAL CONTROL SYSTEM

CDSF THERMAL CONTROL DESIGN DESCRIPTION

The thermal acquisition system is sized for an experiment load of 9.0 kw and an avionics load of 3.0 kw. Heat is acquired by a single-phase pumped water loop with redundant lines and pumps. The experimenters will provide cold plates since only rack connections will be available. The water will be pumped to a freon 21/water interchanger from which single phase freon 21 will be pumped to the radiators along redundant lines. The single phase freon 21 Space Shuttle technology radiators are sized for 12 kw continuous operation with an average environmental sink temperature of -60 degrees C.

CONCEPT 2 THERMAL CONTROL DESIGN DESCRIPTION

Acquisition:

- Sized for 6 kW experiment heat load
- Heat acquired by single-phase pumped water loop
- Avionics cooling provided by OMV
- Experimenters provide cold plates. Rack connections available.
- Subsystem includes redundant lines and pumps

Transport:

- Freon 21/water interchanger
- Pumped single phase freon 21
- Redundant lines and pumps

Rejection:

- Sized for 6 kW continuous operation
- Radiators sized for orbit with average environmental sink temperature of -60°C
- Single phase freon 21 radiators of Space Shuttle technology
  - Emissivity of 0.76
  - Solar absorptivity of 0.11
- Radiator micrometeoroid protection provided

CONCEPT 2 THERMAL CONTROL DESIGN DESCRIPTION

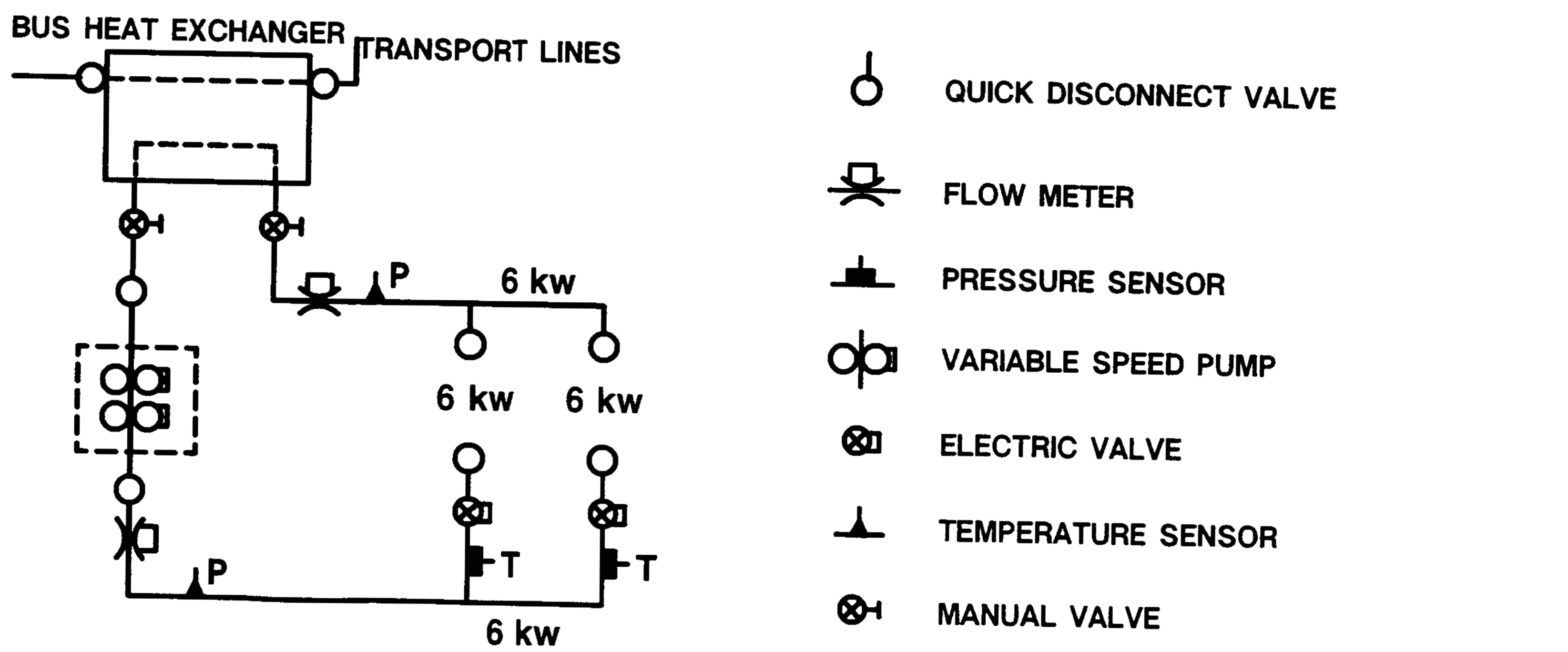
The concept 2 thermal control technologies are shuttle and spacelab derived. The experiment rack heat loads are acquired by pumped single phase water loops operating between 40° to 100° F. Only rack connections are provided for experimenters due to the specialized experiment that may be needed by each user. Avionics are also cooled with cold plates using a single phase pumped water loop. Avionics and rack air cooling were not selected in order for continued operation in case of reduced pressure. A single phase pump freon 21 loop picks up the internal heat load with a freon / water interchanger. For heat rejection to space, the freon is pumped through a set of parallel tubes attached to a micrometeoroid shield. The entire shield acts as the radiating surface.

CDSF #2 THERMAL CONTROL SYSTEM: ACQUISITION

- PRIMARY SYSTEM IS SINGLE PHASE WATER TO COLD PLATES
- SINGLE LOOP SYSTEM SIZED FOR 20,000 BTU/HR

  –ACCOMMODATES HIGH BETA PEAK POWER GENERATION CONDITIONS CONTINUOUSLY

- FULLY REDUNDANT LINES, VALVES, SENSORS AND PUMP PACKAGE



therm sys 20%

CONCEPT 2 ACTIVE THERMAL CONTROL SYSTEM SUMMARY

This is a summary of the thermal control system weight, volume, power, and resupply estimate for CDSF concept #2. This concept weighs approximately half as much as the 100% baseline option, mainly because it provides approximately half the heat rejection (6 kw) capability.

CONCEPT 2 ACTIVE THERMAL CONTROL SYSTEM SUMMARY

Item	Flight Unit Wet Weight (lb)	Flight Unit Dry Weight (lb)	Flight Unit Volume (ft^3)	R = 180 Days		R = 3 Years		R = 5 Years		Power (kW)
				Weight (lb)	Volume (ft^3)	Weight (lb)	Volume (ft^3)	Weight (lb)	Volume (ft^3)	
Experiment Acquisition (6 kW)	183	169	2.7	4	0.1	22	0.3	37	0.5	0.07
Transport	276	186	24.0	4	0.7	13	2.1	26	4.3	0.62
Rejection	358	310	12.0	37	1.6	37	1.6	74	3.2	0
Total	817	665	38.7	45	2.4	72	4.0	137	8.0	0.69

CDSF THERMAL CONTROL SYSTEM WEIGHT BREAKDOWN

A weight breakdown for the thermal control system is presented. The light weight of the rejection system was accomplished by using the micrometeoroid shield as the radiator fin.

CDSF #2 THERMAL CONTROL SYSTEM

	WET	DRY
EXPERIMENT ACQUISITION (6.0KW)	183	169
TRANSPORT	276	186
REJECTION	358	310
SUBTOTAL	817	665
CONTINGENCY (15%)	123	100
TOTAL	940	765

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C-5

6.2.1.3. SCIENCE DATA SYSTEM

SCIENCE DATA SYSTEM

The science data system for the CDSF reduced capability concept is defined to be a data acquisition system that accepts data from the on board experiments and interfaces to the OMV data bus for communications to and from ground flight control. It consists of two on board units. The digital data acquisition and data storage unit is used for handling digital experiment data. The video processing unit uses a store and forward approach for handling experiment television requirements.

SCIENCE DATA SYSTEM

- **CONSISTS OF TWO ELEMENTS**

    1) DIGITAL DATA ACQUISITION & STORAGE UNIT (DDASU)
    2) VIDEO PROCESSING & STORAGE UNIT (VPSU)

- **RACK MOUNTED IN 1/2 OF STANDARD DOUBLE RACK DEDICATED TO AVIONICS**

20% OPTION

SCIENCE DATA SYSTEM

DIGITAL DATA ACQUISITION & STORAGE UNIT (DDASU)	35
VIDEO PROCESSING UNIT (VPU)	21
VPU OMV INTERFACE	12
SUBTOTAL	68
CONTINGENCY (15 %)	10
TOTAL	78

6.2.2. SPACECRAFT BUS AND SYSTEMS DESCRIPTIONS

CDSF CONCEPT 2 SPACECRAFT UTILITY BUS DESCRIPTION

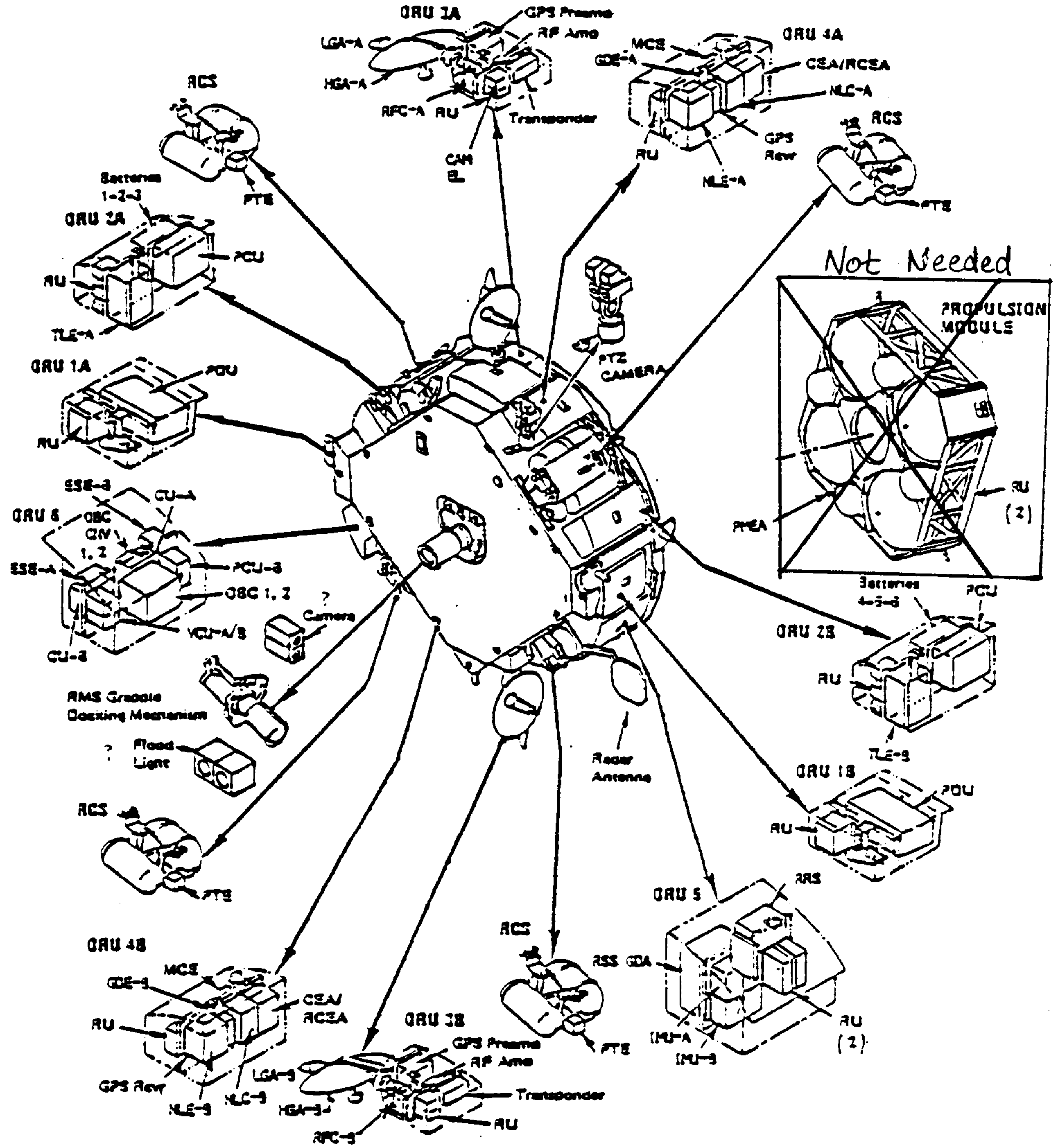
The Orbital Maneuvering Vehicle (OMV) spacecraft short range vehicle (SRV) configuration was chosen as the conceptual free flying utility bus for the CDSF reduced capability concept (Concept 2). The dominant reason for this choice was the orbital reboost system focus of this spacecraft design which closely matches the needs of the CDSF for rendezvous capability with the Space Shuttle. This is a primary concept capability of the OMV design. Also, the OMV development is focused strongly on design compatibility with the appropriate NSTS interface specifications. This is a key consideration that satisfies systems compatibility required for CDSF/STS crew tended missions.

The elements of the OMV that have resupply needs, based on CDSF mission profiles selected, are designed as orbital replaceable units (ORU) with STS compatibility to accommodate revisit missions as needed.

The elements of the OMV also provide all the functional capability needed to support the CDSF experiment module free flier operational mode which includes TDRSS communications compatibility. A power system augmentation module is required to support the power needs of the CDSF experiment module. This interface has already been included as an optional feature in the OMV preliminary design for which interface specifications can currently be provided to the CDSF developer. Other optional elements include the closed circuit television cameras and floodlights which are not essential for CDSF missions.

The following pages depict the OMV SRV configuration and a weight statement is listed.

OMV FLIGHT VEHICLE ELEMENTS



CSA Control Electronics Assembly
CU Central Unit
ESA Earth Sensor Assembly
GEA Gimbal Electronics Assembly
GPS Global Positioning System
IMU Inertial Measurement Unit
MCS Mechanism Control Electronics
NLS Navigation Light Electronics
OBC On-Board Computer
PCU Power Control Unit
PTE Pressure Transducer El
PTZ Pan, Tilt and Zoom
REA Radar Electronics Assembly
VCU Video Compression Unit

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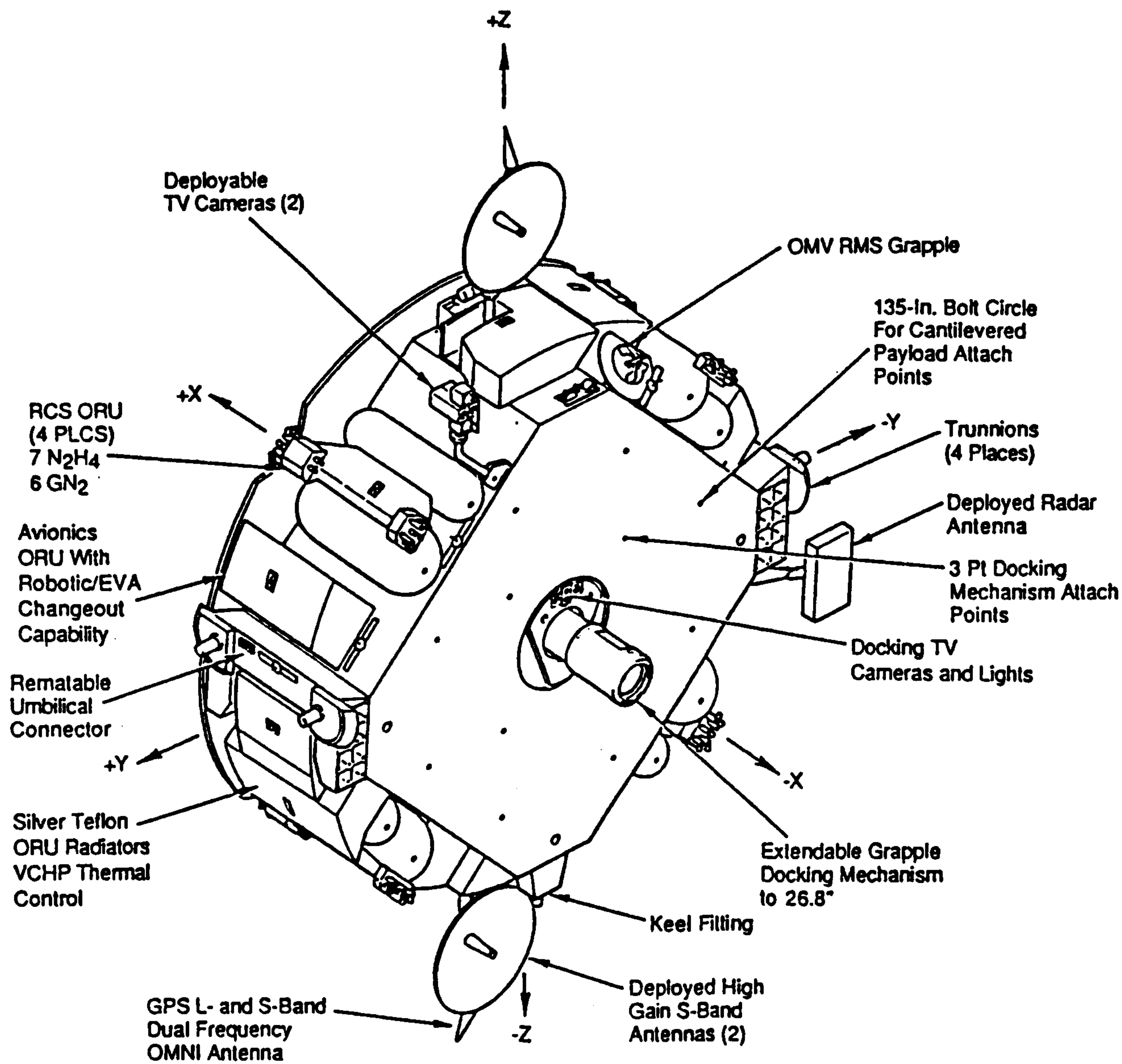
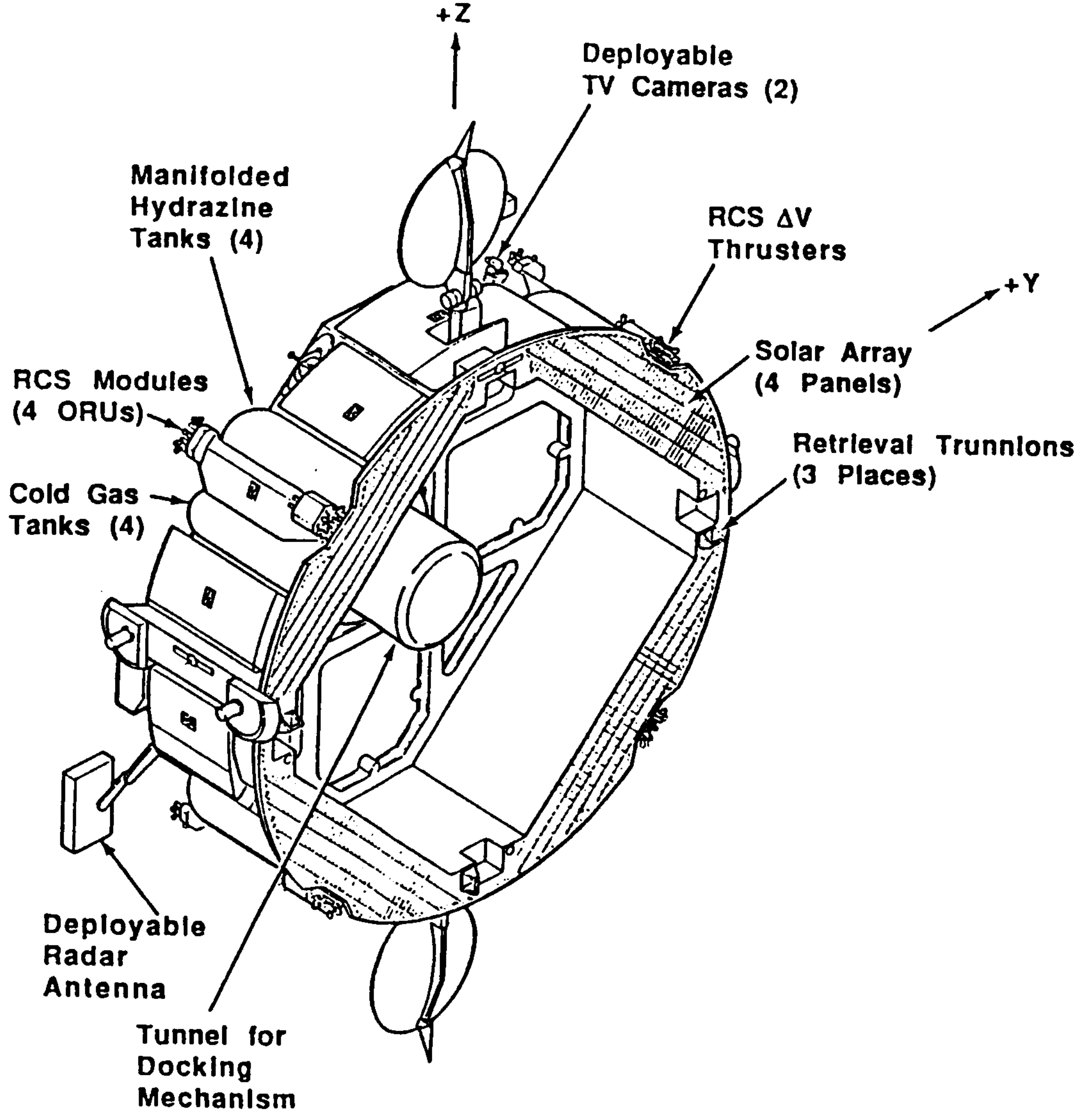
OMV CONFIGURATION: VIEW OF FRONT FACE



OMV CONFIGURATION: VIEW OF BACK FACE



Short Range Vehicle

LENGTH		76 INCHES	
DIAMETER		176 INCHES (14'8")	

WEIGHT SUMMARY (POUNDS)	OMV	PM	SRV
EMPTY (WITH RGDM)	10173	2589	7584
BURNOUT (WITH MAX. RESIDUALS)	10528	2867	7661
MISSION WEIGHT (FULL)	20873	11867	9006
MAX. PROPELLANT (BIPROPELLANT/MONOPROPELLANT/GN_2)	9000/1180/165	9000	1180/165

20% CDSF
Spacecraft Bus

ELECTRICAL POWER	
OPERATING (COAST)	641-1000 WATTS
SPACE-BASED MODE	300 WATTS
ARRAY OUTPUT (57 FT^2)	650 WATTS
PEAK	4500 WATTS
BATTERIES	6 AT 350 AH

COMMUNICATIONS (TDRSS S-BAND)		
HIGH GAIN ANTENNA (2)		SSA MA
OMNI ANTENNA (2)		SSA
MAXIMUM DATE RATES: FORWARD (UPLINK):	TDRSS/GSTDN	1 KBPS/2 KBPS
RETURN (DOWNLINK)		2 X 486 KBPS

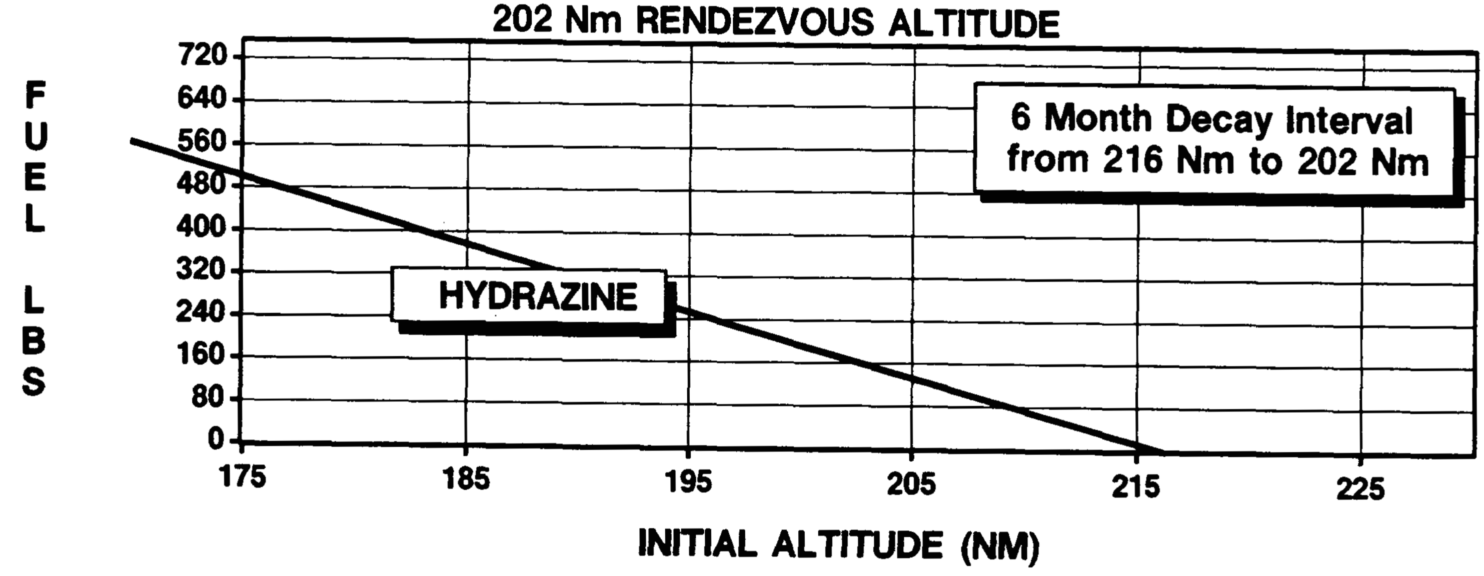
GUIDANCE, NAVIGATION AND CONTROL			
GPS ACCURACY		820 FT (RADIAL)	
RADAR ACQUISITION		4.5 NM, $\pm 20^0$, 5 MIN, $1M^2$	
PROPULSION			
ORBIT ADJUST ENGINES	4	13-130 POUNDS	BIPROP
RCS THRUSTERS	28	12 POUNDS	HYDRAZINE
	24	5 POUNDS	GN_2
ISP-BIPROP/MONOPROP/GN_2	280-300/220/65		

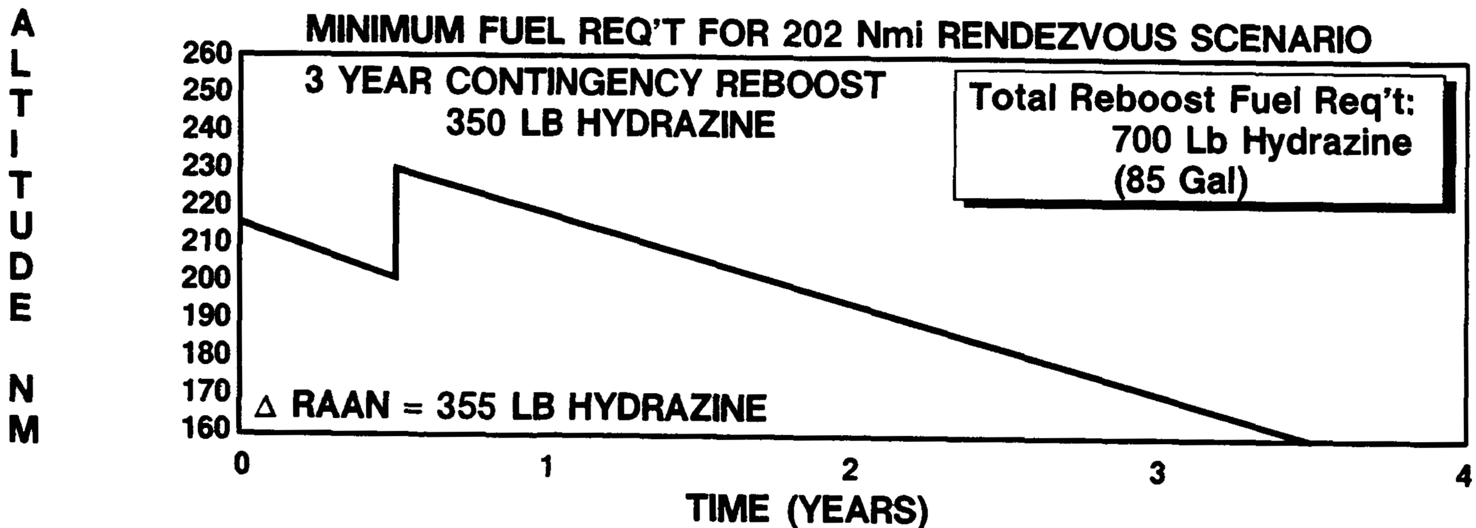
6.2.2.1. PROPELLANT SIZING ANALYSIS

CDSF CONCEPT 2 PROPELLANT REQUIREMENTS (202 NMI RENDEZVOUS)

The reduced capability CDSF Concept 2 is defined to use bi-propellant hydrazine for its reboost propulsion system. This section discusses the analysis performed to quantify orbit altitude propellant requirements. Propellant requirements for both deployment and a 3 year contingency reboost with RAAN (Right Ascension Ascending Node) adjustment are computed for a 202 Nmi rendezvous altitude scenario. The 202 Nmi rendezvous altitude scenario was used for sizing and as the operational baseline. Additional fuel is required if the CDSF is deployed below 216 Nmi and must rendezvous at a preferred repeating orbit altitude of 202 Nmi six months later. Approximately 500 lb of additional hydrazine is required if the CDSF is deployed at 175 Nmi and must rendezvous at 202 Nmi six months later. A 3 year contingency reboost with RAAN adjustment requires 700 lb of hydrazine.

CDSF OPTION 2 PROPELLANT REQUIREMENTS
(SIZING & OPERATIONAL BASELINE)





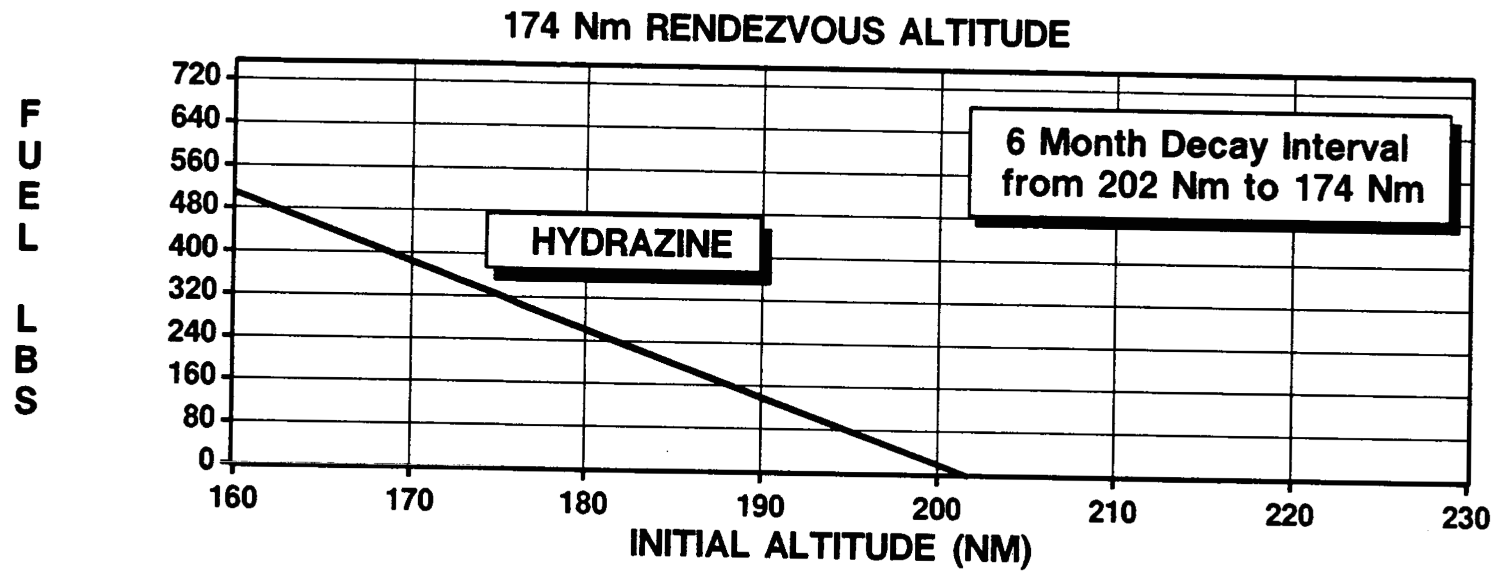
175 NM DEPLOYMENT: 700 + 500 = 1200 LB TOTAL

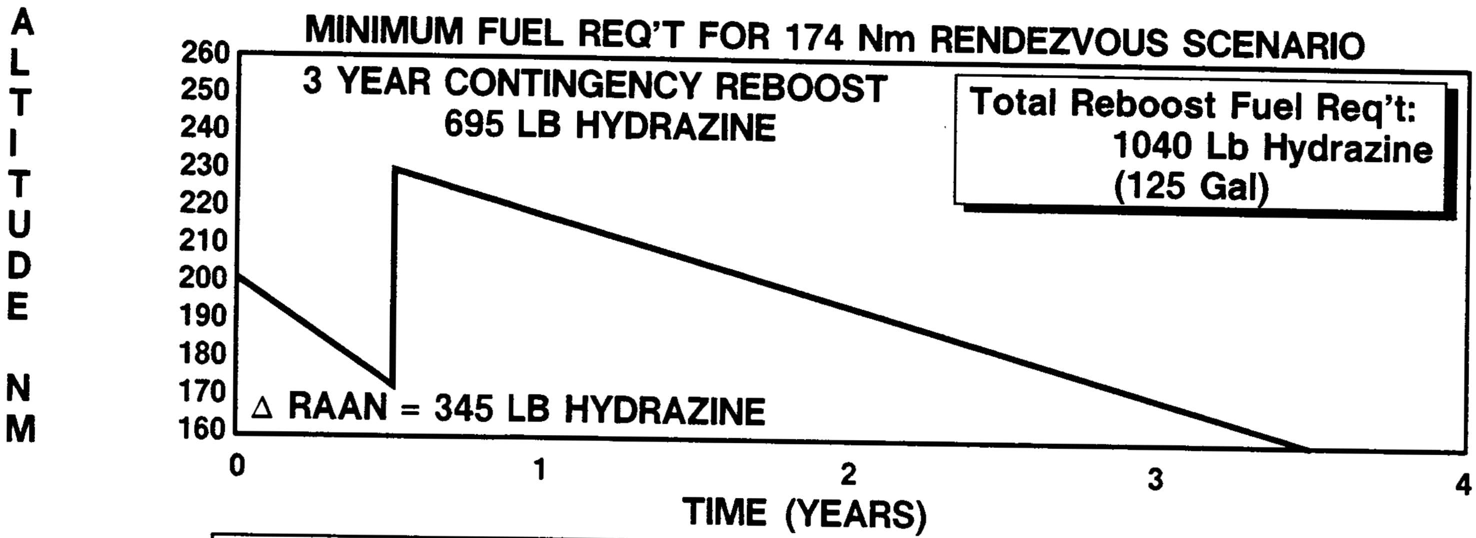
prop 20 option

CONCEPT 2 CDSF PROPELLANT REQUIREMENTS (174 NMI RENDEZVOUS)

The CDSF Concept 2 orbit altitude propellant requirements for both deployment and a 3 year contingency reboost with RAAN adjustment are computed for a 174 Nmi rendezvous altitude scenario. Additional fuel is required if the CDSF is deployed below 202 Nmi and must rendezvous at a preferred repeating orbit altitude of 174 Nmi six months later. Approximately 510 lb of additional hydrazine is required if the CDSF is deployed at 160 Nmi and must rendezvous at 174 Nmi six months later. A 3 year contingency reboost with RAAN adjustment requires 1040 lb of hydrazine.

CDSF OPTION 2 PROPELLANT REQUIREMENTS





160 NM DEPLOYMENT: 1040 + 510 = 1550 LB TOTAL

prop 20 baseline

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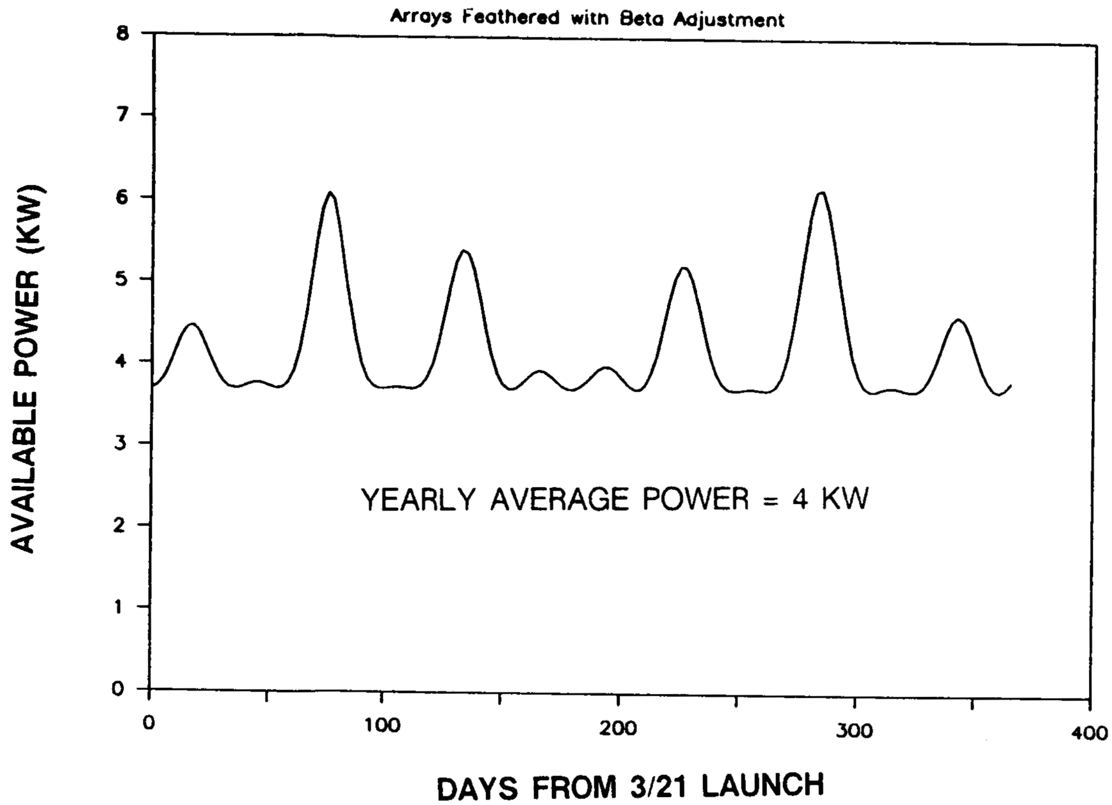
6.2.3. 3.5 KW POWER AUGMENTATION MODULE

CDSF CONCEPT 2 POWER SYSTEM SIZING

The CDSF Concept 2 provides a yearly average power capability of 5 kW when the solar array is feathered with beta adjustment. With an allocation of 1 kW for spacecraft bus general housekeeping, a yearly average power of 4 kW is available to the user. Available power varies from 3.7 kW to 6 kW with power greater than 5 kW four times (50 days total) per year.

20% CDSF CONCEPT POWER SYSTEM SIZING

- **20% CDSF HAS 5 kW AVG POWER CAPABILITY**
  - 1 kW SPACECRAFT BUS (GENERAL HOUSEKEEPING)
  - 4 kW POWER AUGMENTATION MODULE
- **POWER AUGMENTATION MODULE PROVIDES 3.7 / 6 kW LOW / HIGH BETA CAPABILITY**
  - POWER AT BUS > 5kW OCCURS 50 DAYS (2 X 15 DAYS, 2 X 10 DAYS) PER YEAR

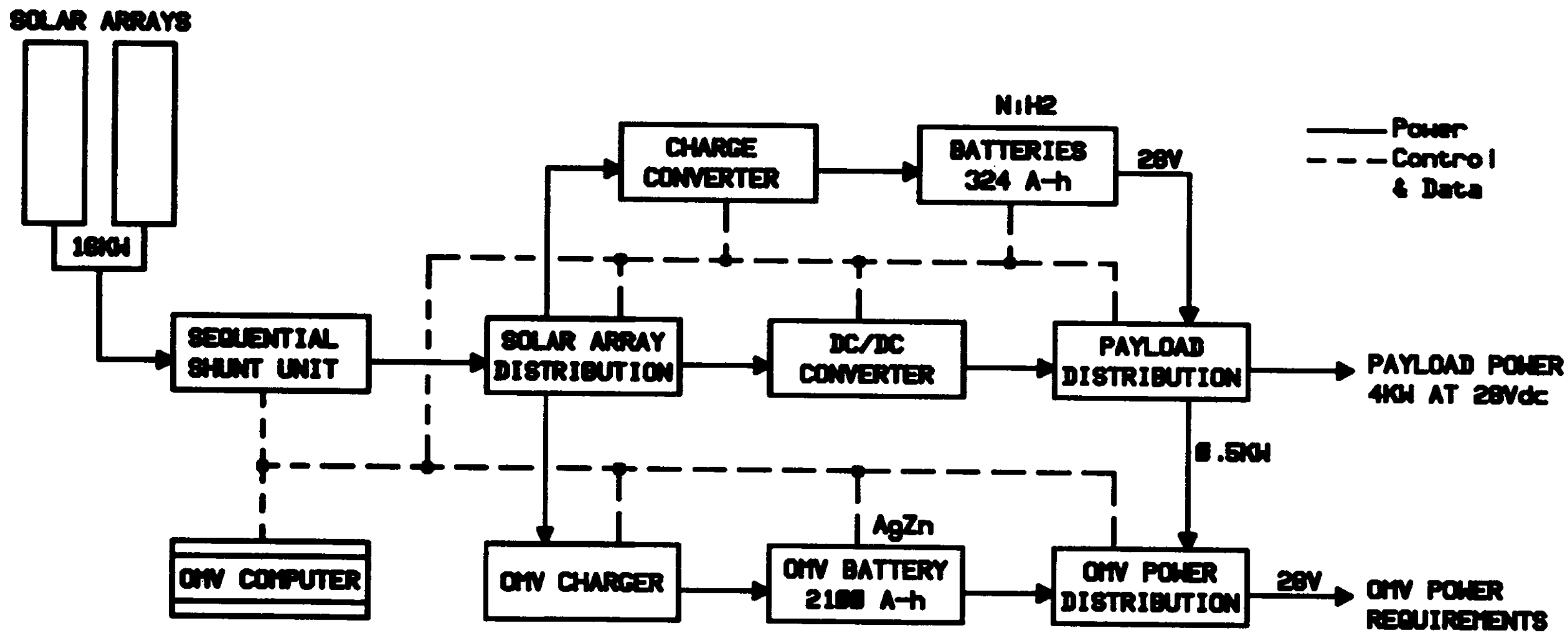


CDSF CONCEPT 2 SPACECRAFT CONCEPT

The spacecraft bus is proposed to be an Orbital Maneuvering Vehicle (OMV) currently being developed by TRW Space & Technology Group for MSFC. It is proposed to use the OMV Short Range Vehicle as configured at its PDR August 22, 1988 without modification. Propulsion, communications, and some housekeeping power are to be supplied to the CDFS from the OMV.

Because of the large power requirements for the CDSF, a Power Augmentation Module (PAM) is required. It is proposed to use the volume in the OMV allocated for the Propulsion Module for the CDSF PAM. It is anticipated that the design of the structure for the PAM would be very similar to design of the structure for the Propulsion Module. Mounted on the external face of the PAM is a 3080 square foot solar array with its deployment and beta tracking mechanisms.

20% CDSF/OMV ELECTRICAL POWER SYSTEM
28Vdc DISTRIBUTION BUS (Redundant)



CDSF CONCEPT 2 POWER SYSTEM EFFICIENCIES

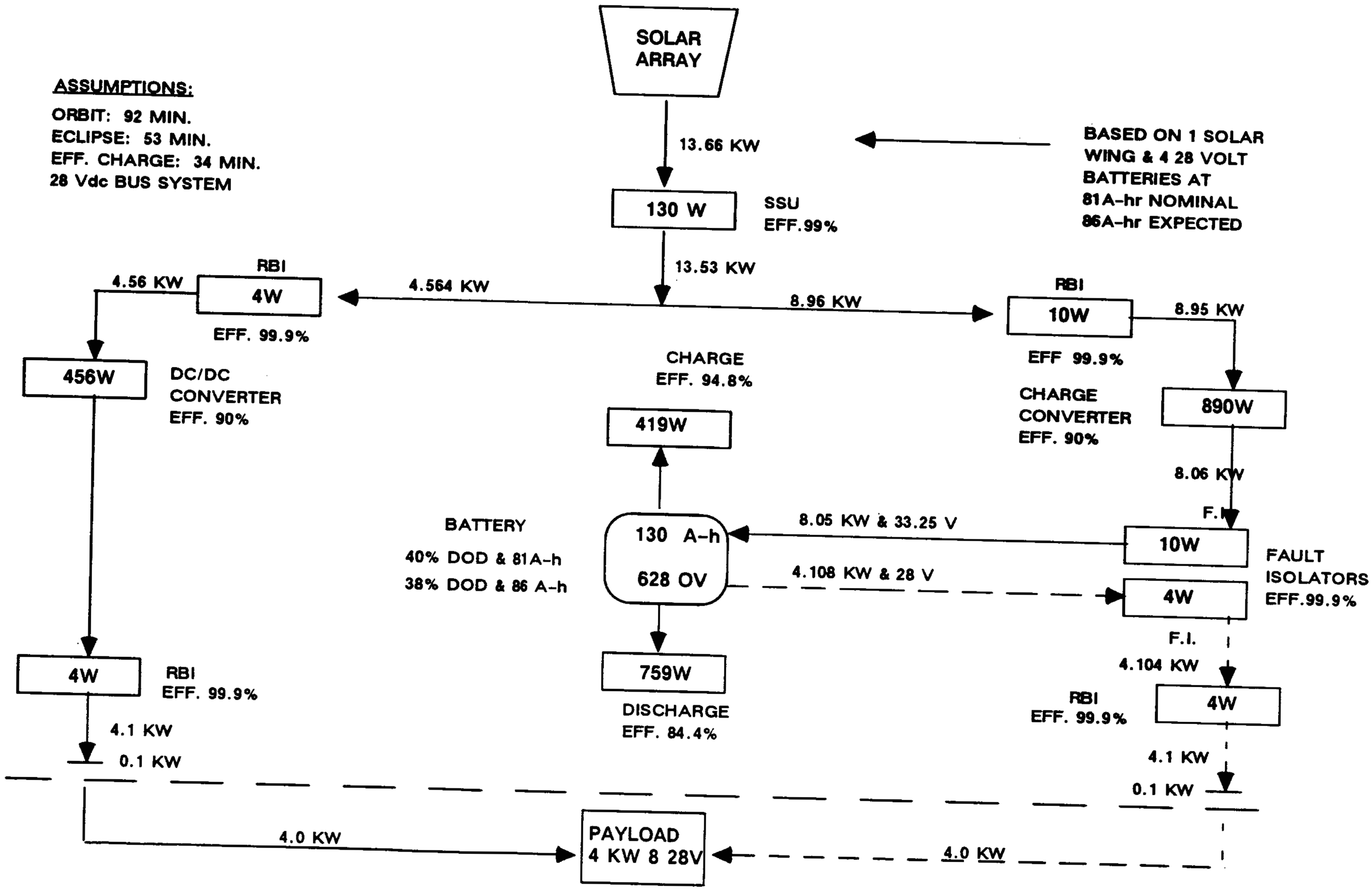
The facing page depicts the power losses in the 28-volts dc system with a 4kW load. The calculations were also based upon a 92 minute orbit with a 53 minute eclipse and effective charge time of 34 of the 39 sunlight minutes. The five (5) minute difference is recommended for charge margin and thermal stabilization time. The average power output from the solar array would have to be 13.66 kW to recharge the batteries and furnish 4kW to the load. The batteries would discharge to a depth of 38 to 40%. The maximum DOD for NiH2 batteries can be 80%.

20% CDSF POWER SYSTEM EFFICIENCIES

4 KW AVERAGE POWER - 28 Vdc Bus System

ASSUMPTIONS:

ORBIT: 92 MIN.
ECLIPSE: 53 MIN.
EFF. CHARGE: 34 MIN.
28 Vdc BUS SYSTEM



MNC2

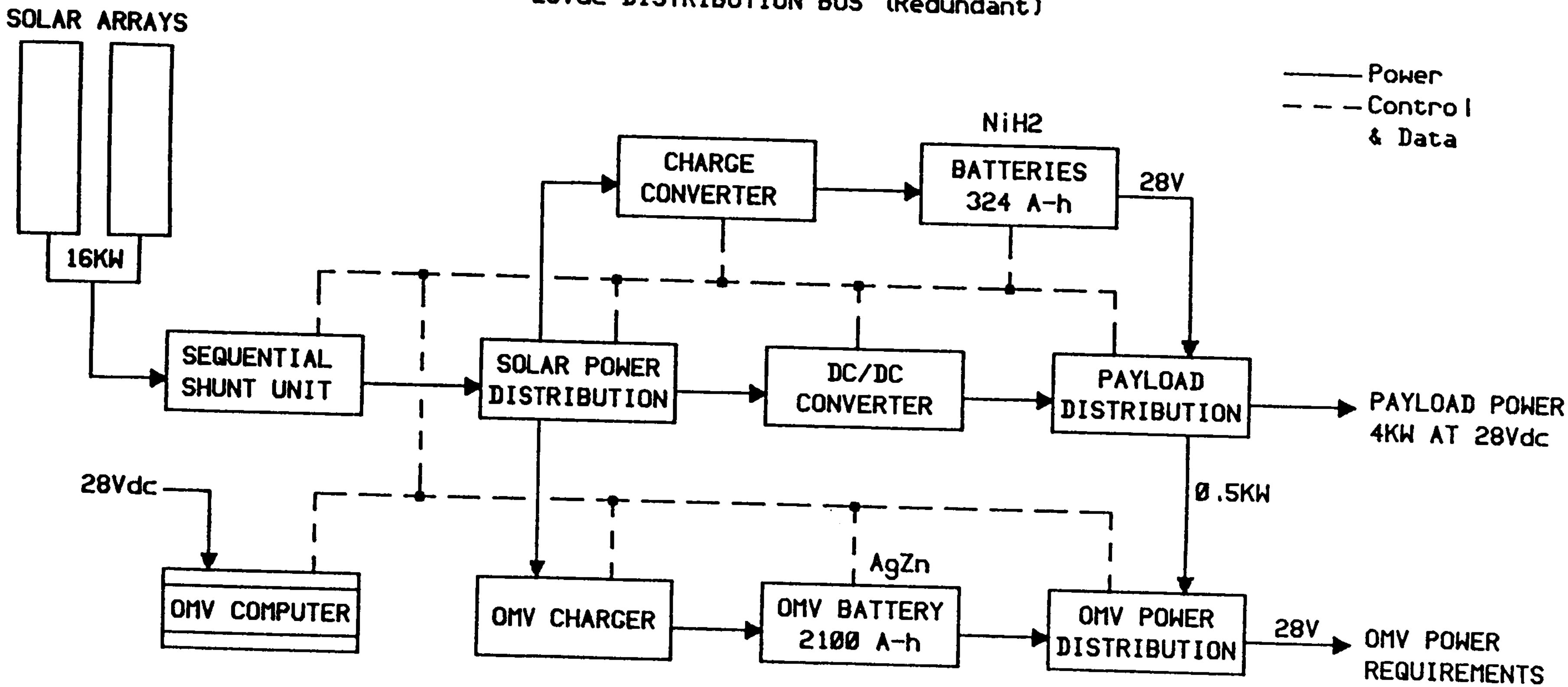
CDSF CONCEPT 2 ELECTRICAL POWER SYSTEM

The facing page illustrates the electrical power system of the Concept 2 CDSF using a Power Module (PM) in conjunction with the NASA Orbital Maneuvering Vehicle (OMV). The 16kW average from the solar array is controlled through a Sequential Shunt Unit (SSU), distributed to the charge converters and dc/ac converter to the 4kW, 28Vdc, payload distribution buses. The electrical power system would be controlled by the OMV computer.

The CDSF PM battery power would be furnished by four (4) 28Vdc, 81 ampere-hour NiH_2 batteries.

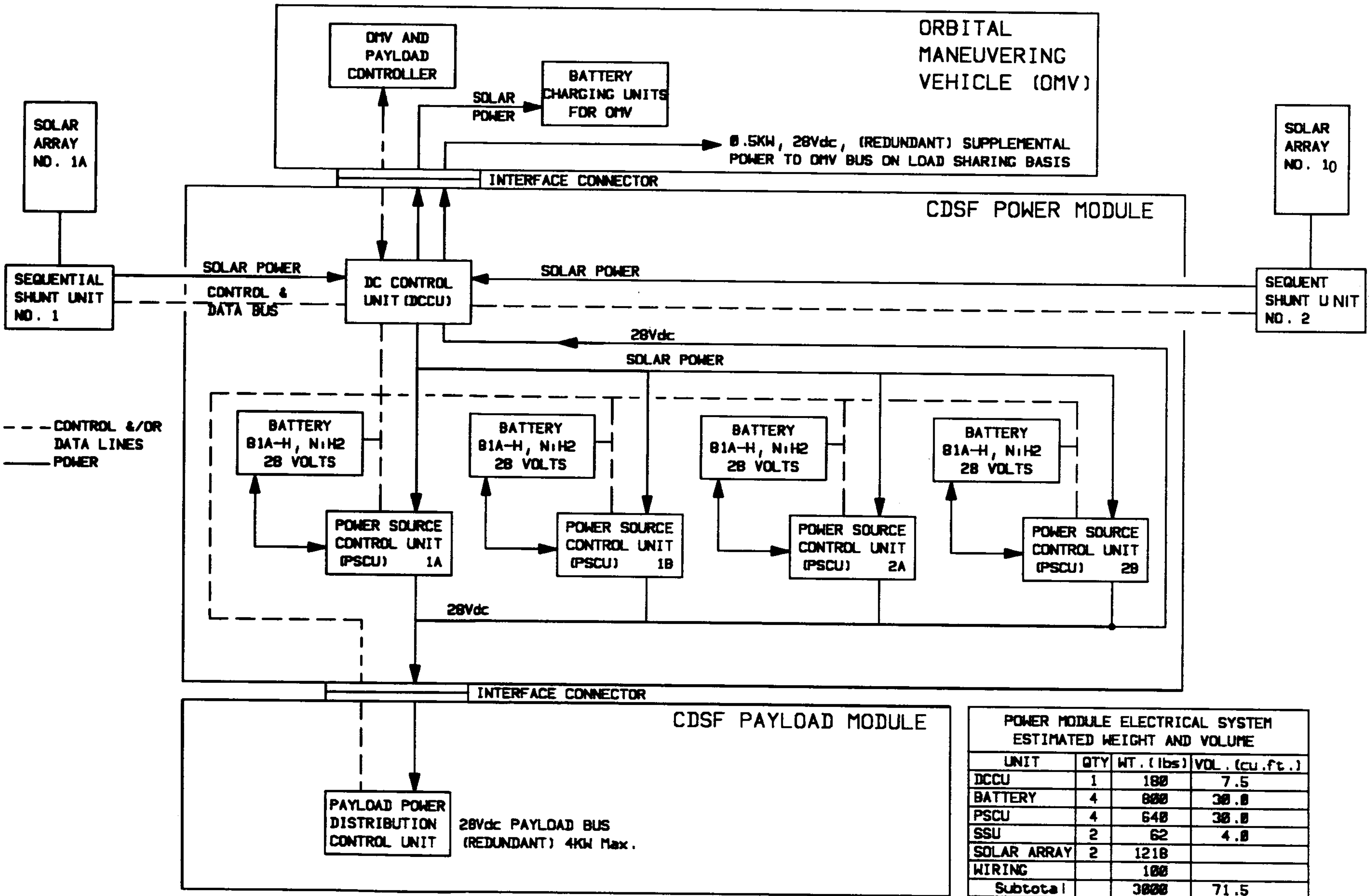
CDSF-2Ø/OMV ELECTRICAL POWER SYSTEM

28Vdc DISTRIBUTION BUS (Redundant)



CDSF - CONCEPT 2 - USING OMV

The facing page depicts a more detailed block diagram showing the CDSF Payload Module, Power Module, and OMV components. The solar array shall be divided to supply redundant 2kW busses. An estimated weight and volume chart for the Power Module is also shown.



POWER MODULE ELECTRICAL SYSTEM
ESTIMATED WEIGHT AND VOLUME

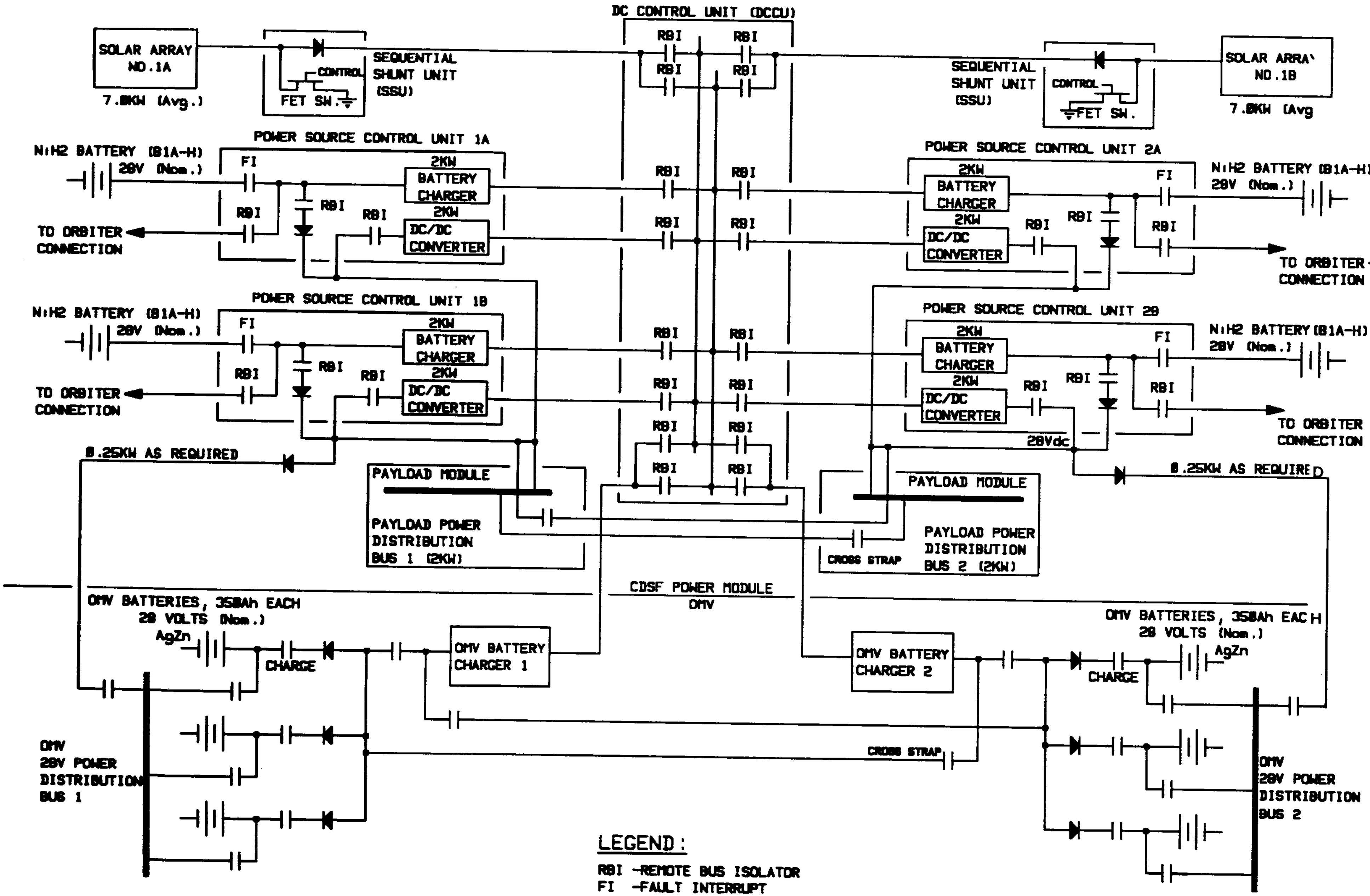
UNIT	QTY	WT. (lbs)	VOL. (cu.ft.)
DCCU	1	180	7.5
BATTERY	4	800	30.0
PSCU	4	640	30.0
SSU	2	62	4.0
SOLAR ARRAY	2	1218	
WIRING		100	
Subtotal		3000	71.5
+15%		450	10.7
TOTAL		3450	82.2

20% CDSF CONCEPT - USING OMV

SF010689

CDSF CONCEPT 2 POWER DISTRIBUTION SYSTEM

The schematic diagram illustrates the redundancy of the system and the switching involved. A 7kW average power output is required from the each solar array section to provide the power necessary to recharge the batteries and furnish the 2kW to the power distribution bus during the sunlight portion of the orbit. The OMV computers would perform the power management functions. It may be necessary to provide power to the OMV to recharge batteries depending on the depletion rate of the OMV batteries.



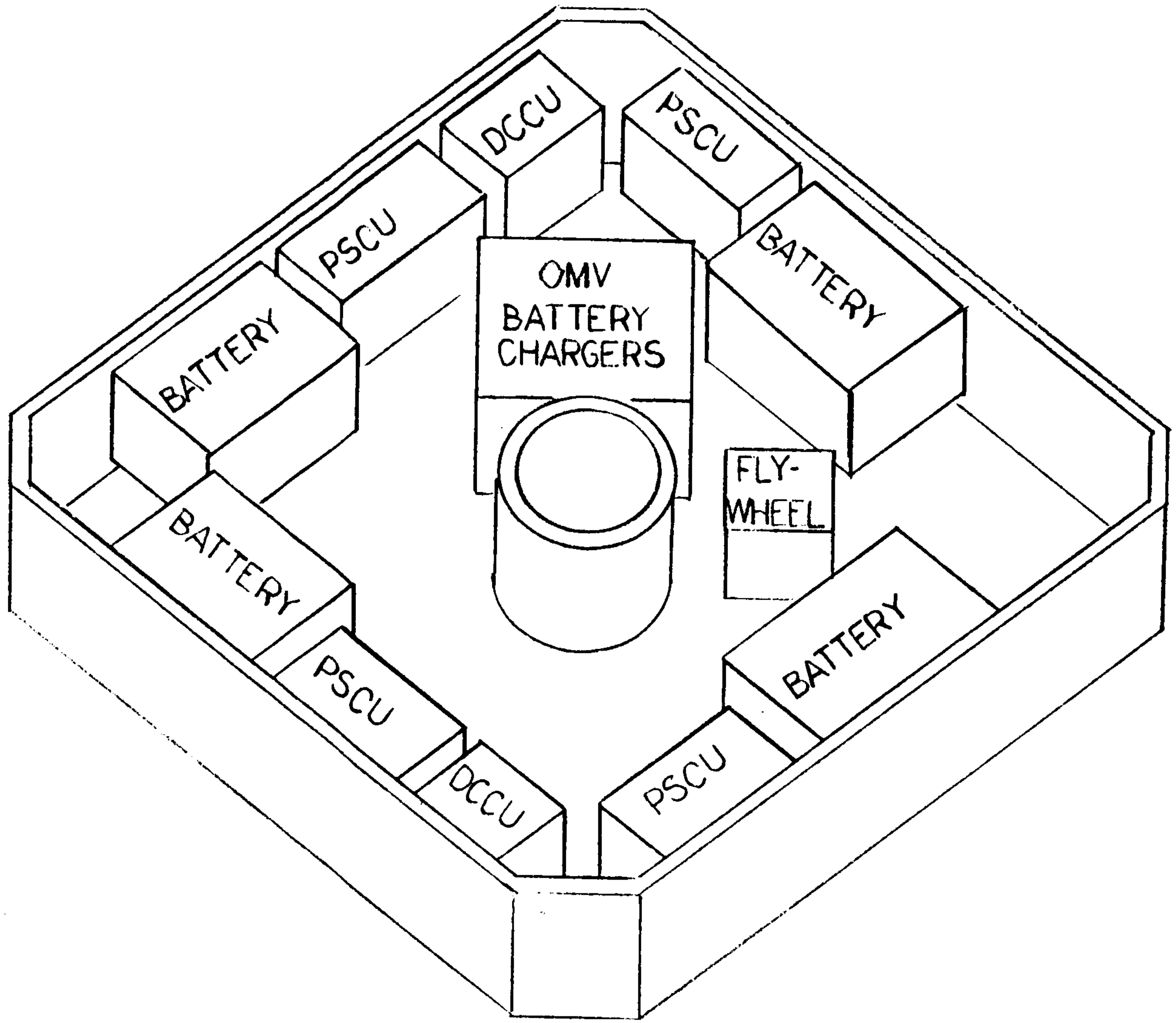
20% CDSF POWER DISTRIBUTION SYSTEM

SF011289

INTERNAL LAYOUT OF POWER AUGMENTATION MODULE

Located internal to the PAM is the equipment required for power conditioning and energy storage. The PAM would also house any momentum wheel which might be required for spacecraft stability. It is proposed that the PAM be designed for on-orbit replacement of any of the internal ''black boxes."

INTERNAL LAYOUT OF POWER AUGMENTATION MODULE

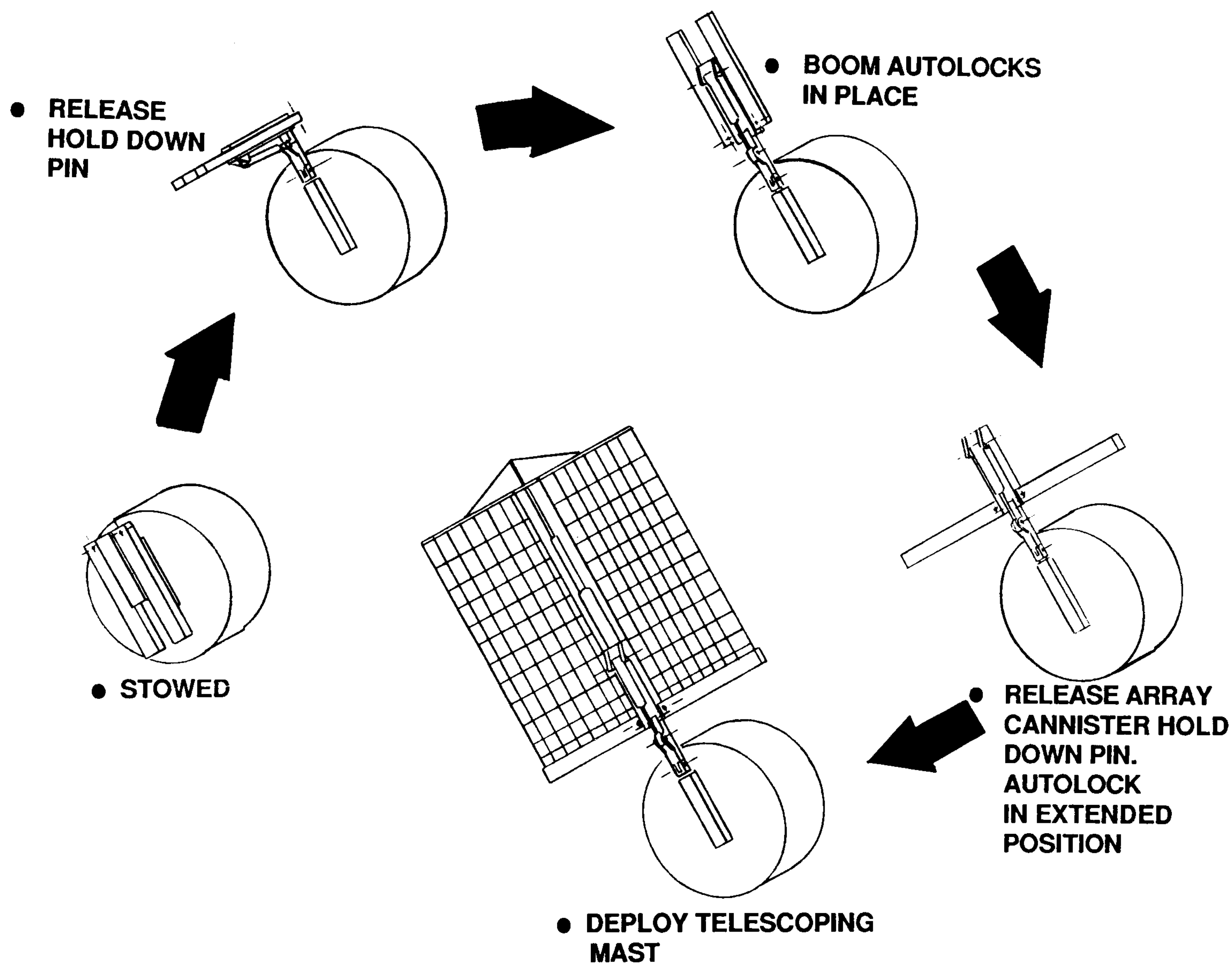


CDSF CONCEPT 2 SOLAR ARRAY DEPLOYMENT

Deployment of the solar array is proposed to be a four step process. First, a release mechanism is activated to allow the structure housing the solar array and it's deployment mechanism to rotate 90 degrees perpendicular to the plane of the PAM. Next, the mechanism to be used to position the solar array for reboost or for mating with the STS rotates the structure another 90 degrees parallel to the plane of the PAM. Third, a mechanism constraining the containers housing the solar array is activated and the containers rotate 90 degrees to be in line. Finally, a deployment mechanism using Space Station Freedom type technology is proposed to deploy the array.

The structure supporting the solar array is proposed to contain a mechanism to rotate the array about it's longitudinal centerline for beta tracking the sun. This same mechanism will also allow the array to be rotated 180 degrees and, used in conjunction with the actuator in step two above, will position the array for reboost or mated operations.

20% CDSF SOLAR ARRAY DEPLOYMENT CONCEPT



CDSF CONCEPT 2 OPTION

A weight allocation is given for the Electrical Power System onboard the CDSF Concept 2. Component weights are presented for the CDSF with feathered solar array and beta adjustment.

CDSF CONCEPT 2 OPTION

<u>3.5 kW POWER AUGMENTATION MODULE</u>

SOLAR ARRAYS (2)	1218
STRUCTURE	435
SOLAR ARRAY SHUNT UNITS (2) (SSU)	62
BATTERY CHARGE CONTROL (2) (BCC)	640
BATTERIES (4)	800
DC CONTROL UNIT (DCCU)	180
WIRING	100
THERMAL	87
SUBTOTAL	3522
CONTINGENCY (15%)	528
TOTAL	4050

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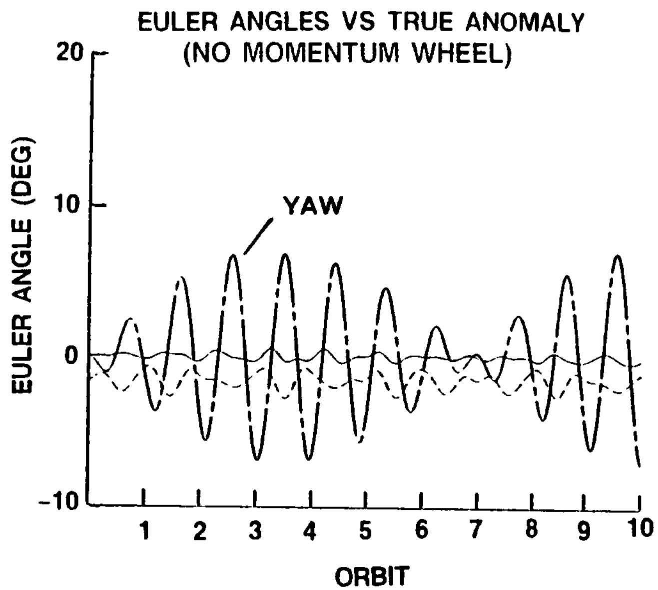
6.2.4. MICROGRAVITY STABILITY ANALYSIS

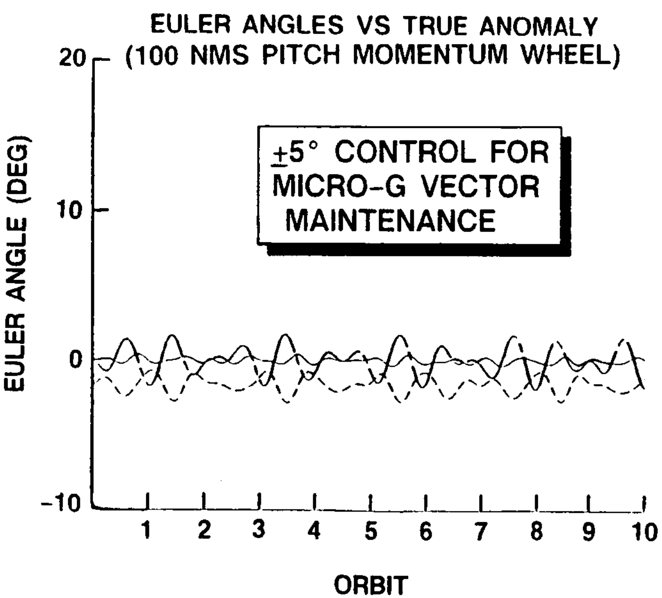
FREE FLYER MICRO-G FLIGHT STABILITY ANALYSIS

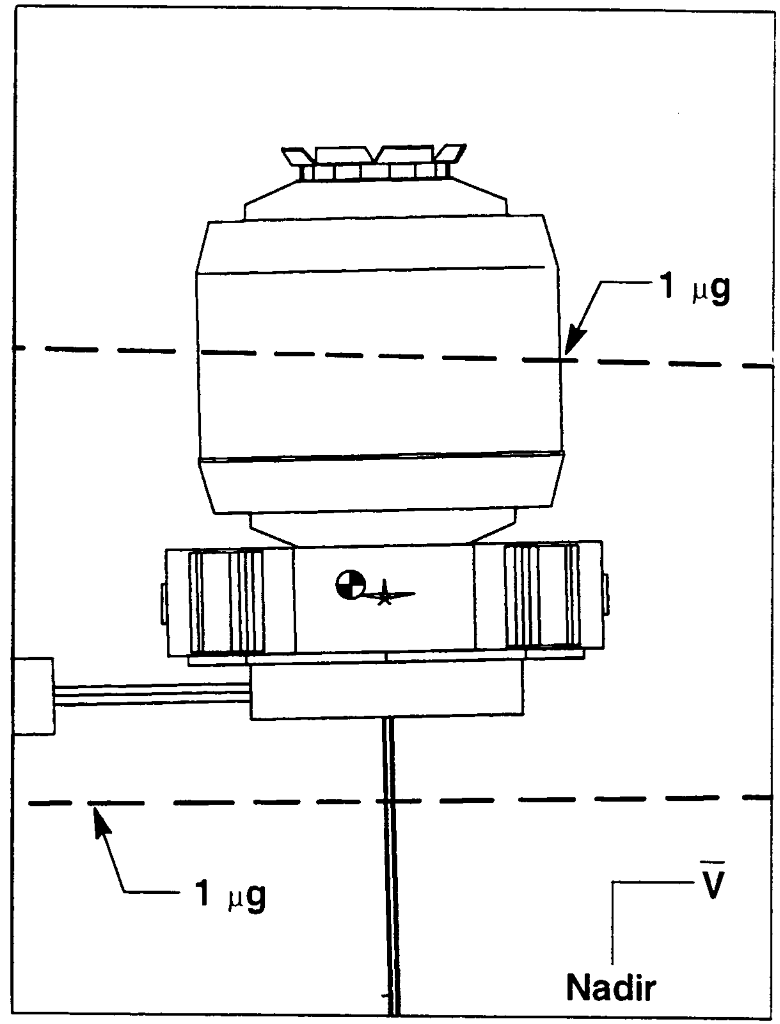
The Concept 2 CDSF free-flyer configuration was analyzed to determine passive stability characteristics. As with the Concept 1, a gravity gradient boom is required to achieve stability about the pitch axis. Concept 2 exhibits only marginal passive gravity gradient stability characteristics with the array along V-bar oscillating by up to plus or minus 8 degrees in yaw. The addition of a 100 NMS pitch momentum wheel controlled the yaw oscillations to less than 2.5 degrees amplitude to meet the desirable ±5 degree limit cycle stability for microgravity experiment operation. This assessment was performed assuming a 180 Nm altitude, and a "best estimate" atmosphere profile as defined by the Marshall Space Flight Center.

With the vehicle center of mass located at the position shown, the experiment rack locations are within a volume that exhibits a one micro-G steady state acceleration level for the flight attitude orientation depicted.

FREE FLYER MICRO-G FLIGHT STABILITY ANALYSIS







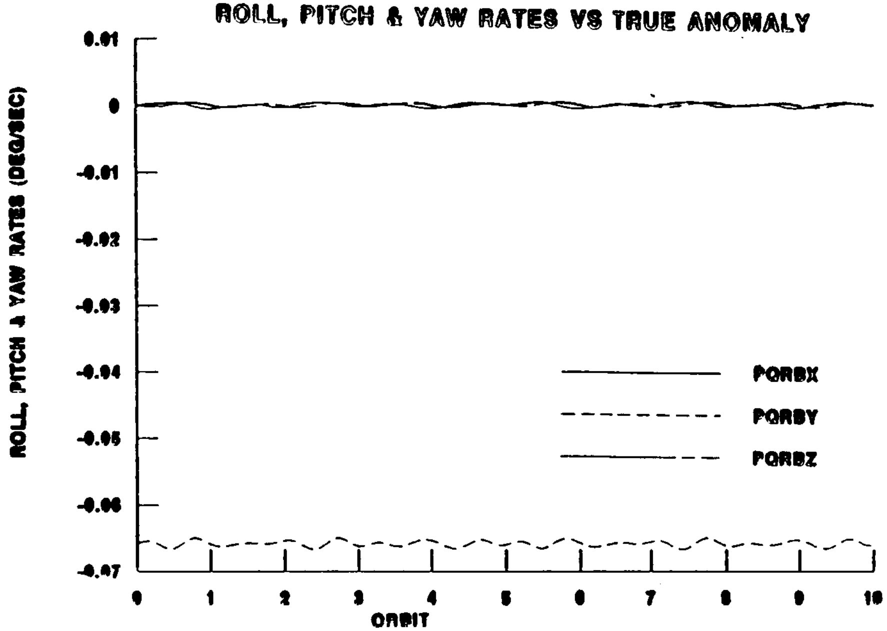
BEST ESTIMATE MSFC/J70 ATMOSPHERE
SOLAR FLUX = 131, AP = 20.7
ALTITUDE = 180 NMI
PITCH DRIFT RATE = ±0.005 DEG/SEC
DATE = MARCH 1993

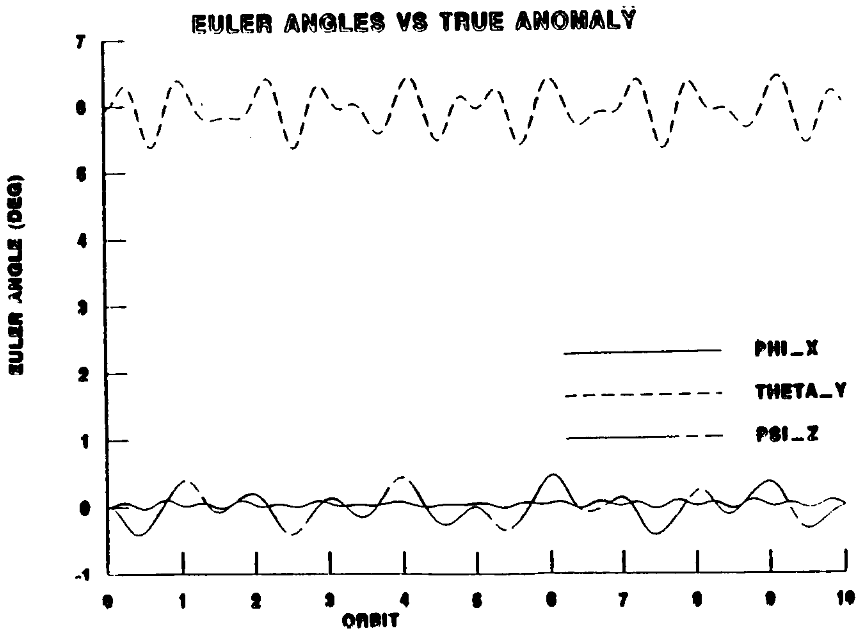
CREW TENDED MICRO-G FLIGHT STABILITY ANALYSIS

An attitude stability analysis of the Concept 2 mated configuration option was performed to determine whether or not active attitude control devices are required to achieve the desired attitude stability of at least ± 5 degrees. Results indicate that the mated configuration is stable with the Orbiter flying nose down, wings perpendicular to the orbit plane (POP), CDSF horizontal with respect to the Earth surface with the array along V-bar. In such a configuration, the Concept 2 CDSF experiences approximately a 3 micro-g sensed acceleration level.

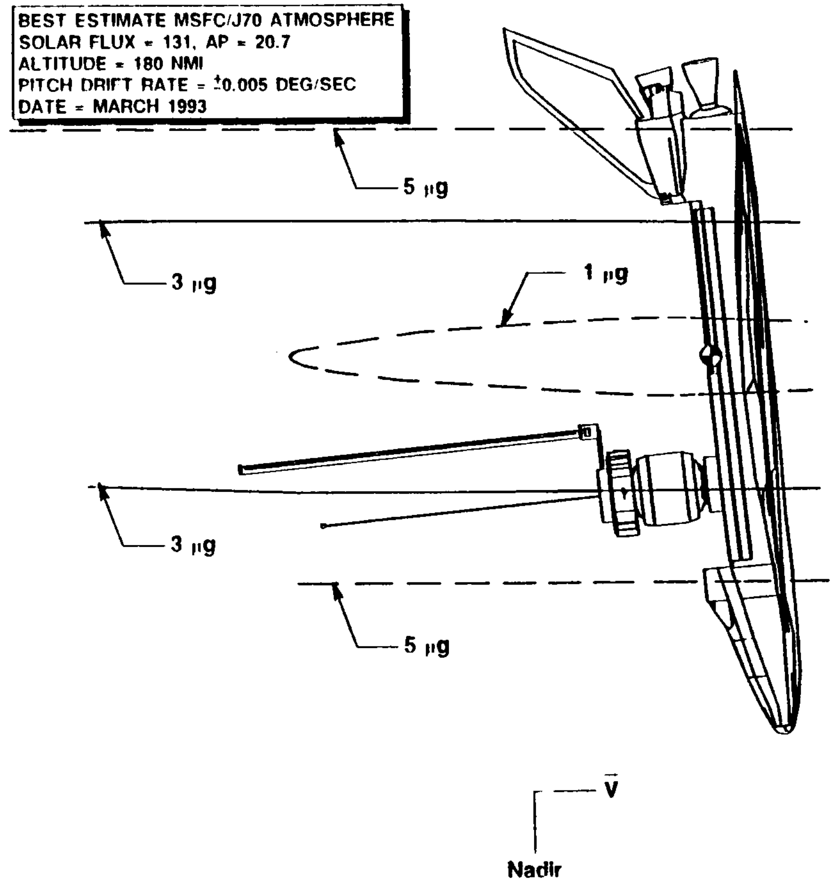
Analysis results show that the active control devices are not required for this configuration. Passive stability is maintained at a (0.0, +6.0, 0.0) degree roll, pitch, yaw attitude within ± 1 degree about any axis.

CREW TENDED MICRO-G FLIGHT STABILITY ANALYSIS





- GRAVITY GRADIENT ASSISTED PASSIVE STABILITY



NASA

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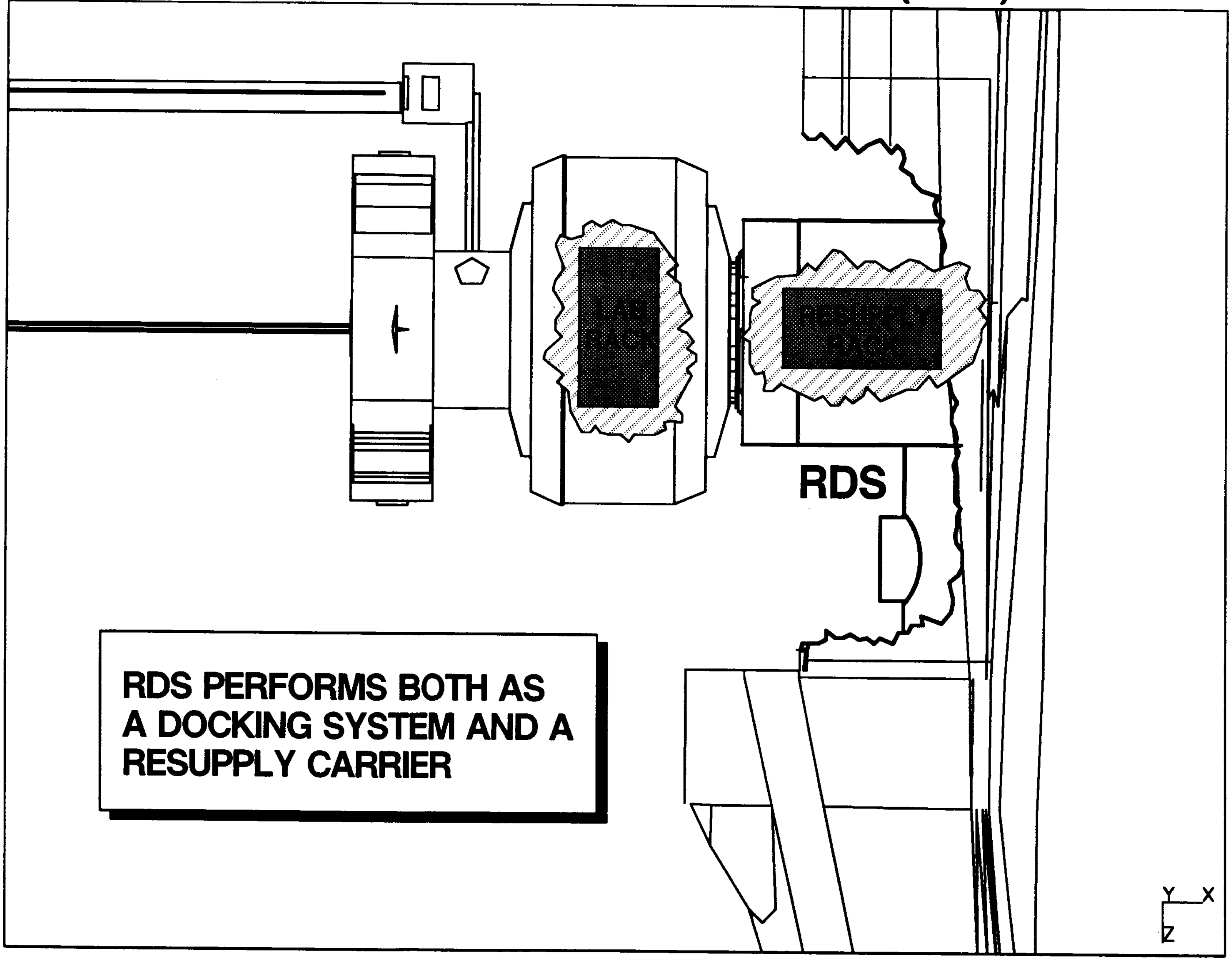
6.2.5. RESUPPLY/DOCKING MODULE

RESUPPLY / DOCKING SYSTEM (RDS)

The RDS combines the functions of a docking system and a resupply module. It is mounted forward in the orbiter cargo bay and is connected to the orbiter mid deck by a short pressurized tunnel that contains a hatch used for EVA. The main pressurized chamber of the RDS is a 13.5 foot diameter truncated cylinder 10 feet in length with a CDSF berthing port located at the top. This chamber is used to store CDSF racks for experiment change out when the CDSF is berthed to the top of the RDS.

RESUPPLY / DOCKING SYSTEM (RDS)



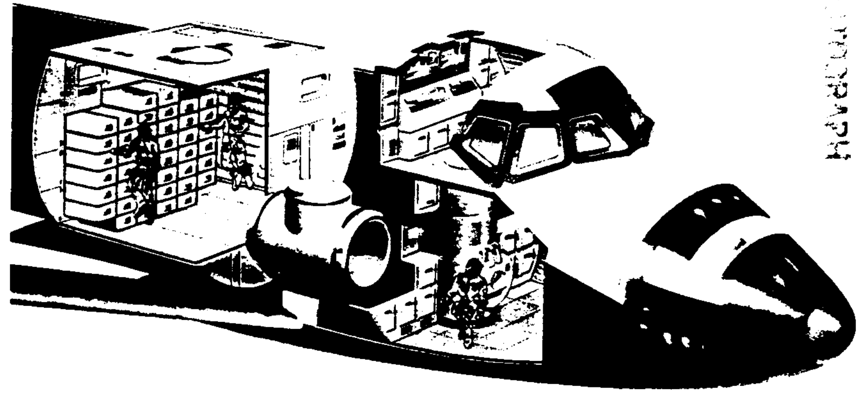
CDSF CONCEPT #2 RESUPPLY / DOCKING SYSTEM

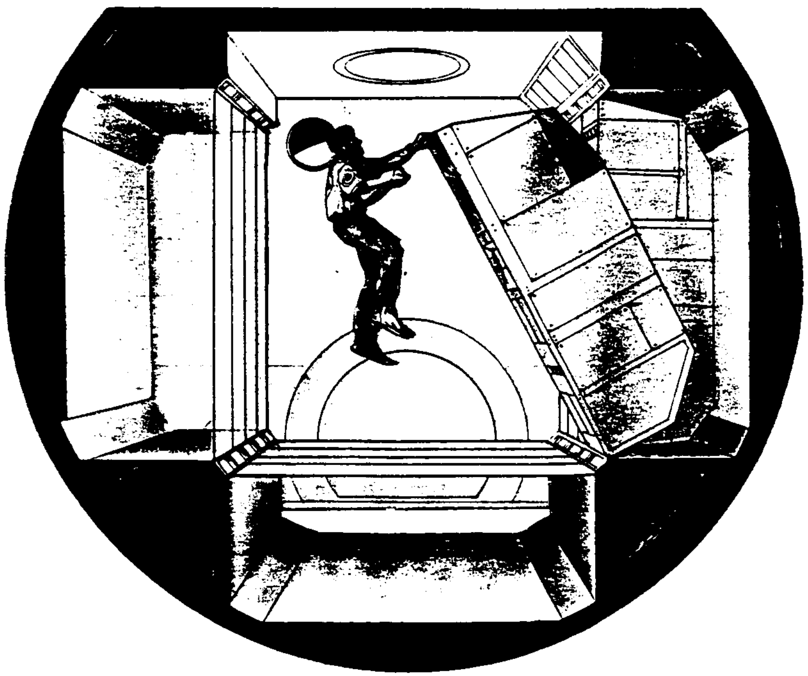
The RDS has almost 1000 cubic feet of pressurized volume that can accommodate 2 CDSF double racks and some orbiter mid deck type lockers that could be used for additional experimentation. Rack changeout between the RDS and the CDSF is done one rack at a time through the 46" hatch.

The concept for combining the Resupply and Docking functions in a single module design was derived by the NASA in-house study team from information provided by Mr. Tom Taylor, Director of Engineering, SPACEHAB incorporated.

20% CDSF CONCEPT RESUPPLY / DOCKING MODULE

- 13.5' DIAMETER TRUNCATED CYLINDER -- 10' LENGTH
- 1000 FT^3 PRESSURIZED VOLUME
- WEIGHT = 7390 LBS
- 46" CDSF BERTHING PORT IN TRUNCATED FLAT





- 132 FT^3 TOTAL EXPERIMENT CAPACITY
- ACCOMMODATES 2 CDSF DOUBLE RACKS FOR EXPERIMENT CHANGE OUT (80 FT^3)

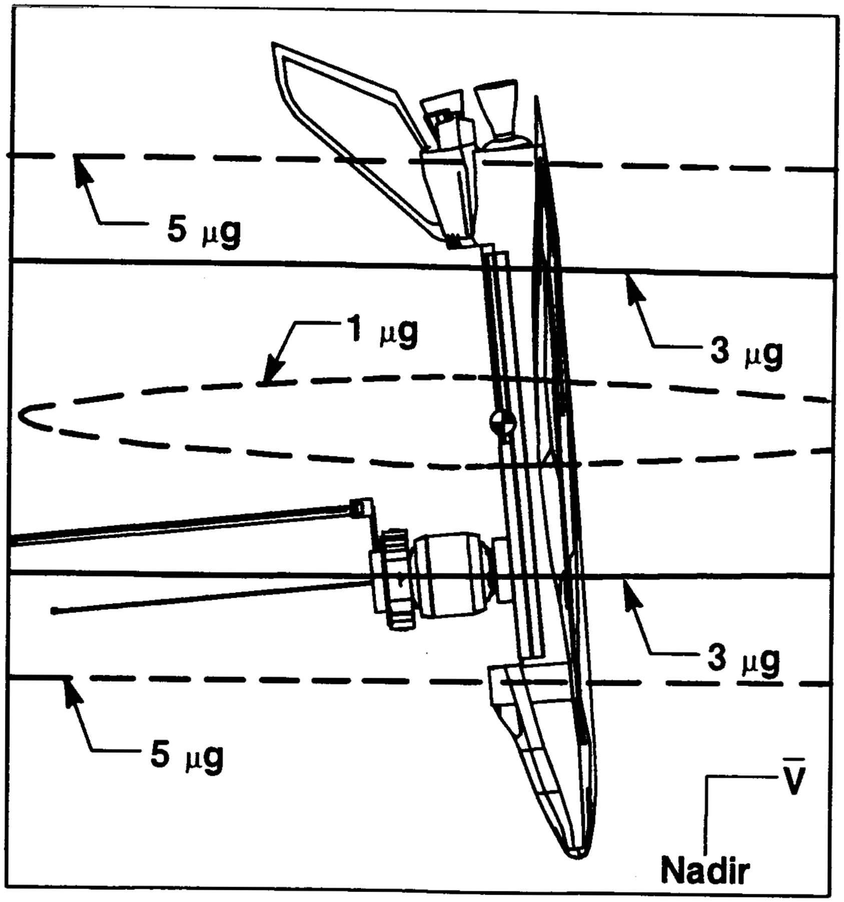
CDSF CONCEPT #2 TUNNEL OPTIONS

The tunnel connecting the RDS to the orbiter results in a mated CDSF/orbiter configuration that yields at best a three micro-g steady state environment in the CDSF. A tunnel that is 25 feet longer would move the berthing port so that it would be coincident with the orbiter center of mass resulting in a mated configuration that yields a one micro-g steady state environment. This "long tunnel" option permits the CDSF concept #2 mated configuration to meet the desired micro-g environment.

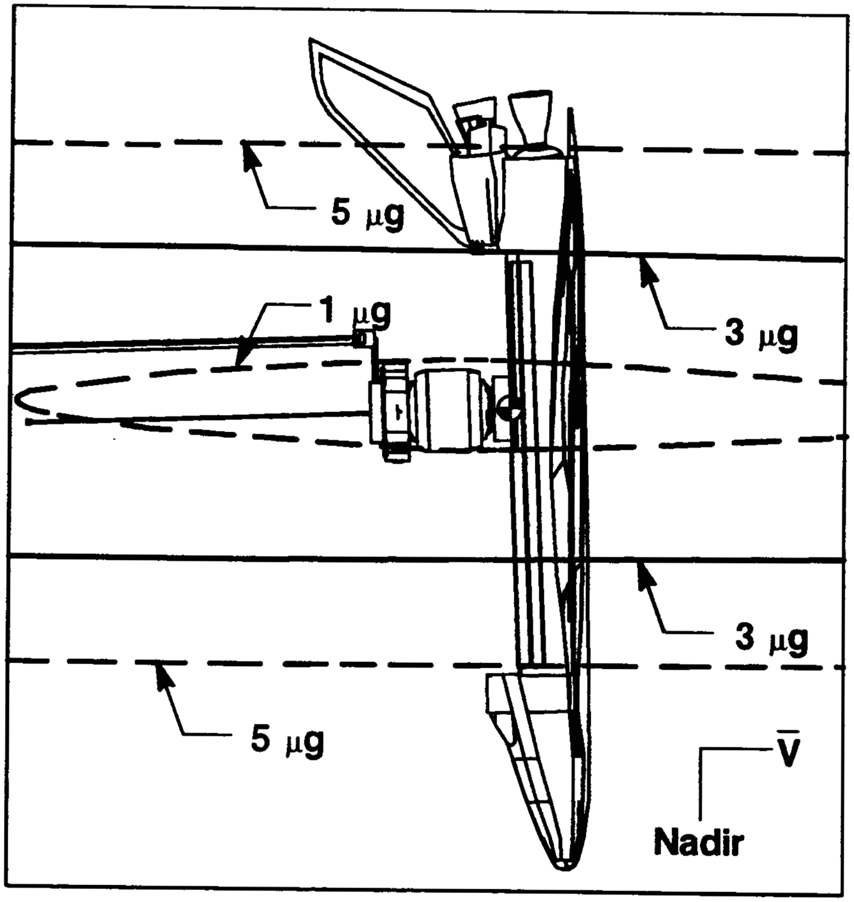
CDSF CONCEPT #2 TUNNEL OPTIONS

BEST ESTIMATE MSFC/J70 ATMOSPHERE
SOLAR FLUX = 131, AP = 20.7
ALTITUDE = 180 NMI
PITCH DRIFT RATE = ±0.005 DEG/SEC
DATE = MARCH 1993

SHORT TUNNEL - 3 μg STEADY STATE



LONG TUNNEL - 1 μg STEADY STATE

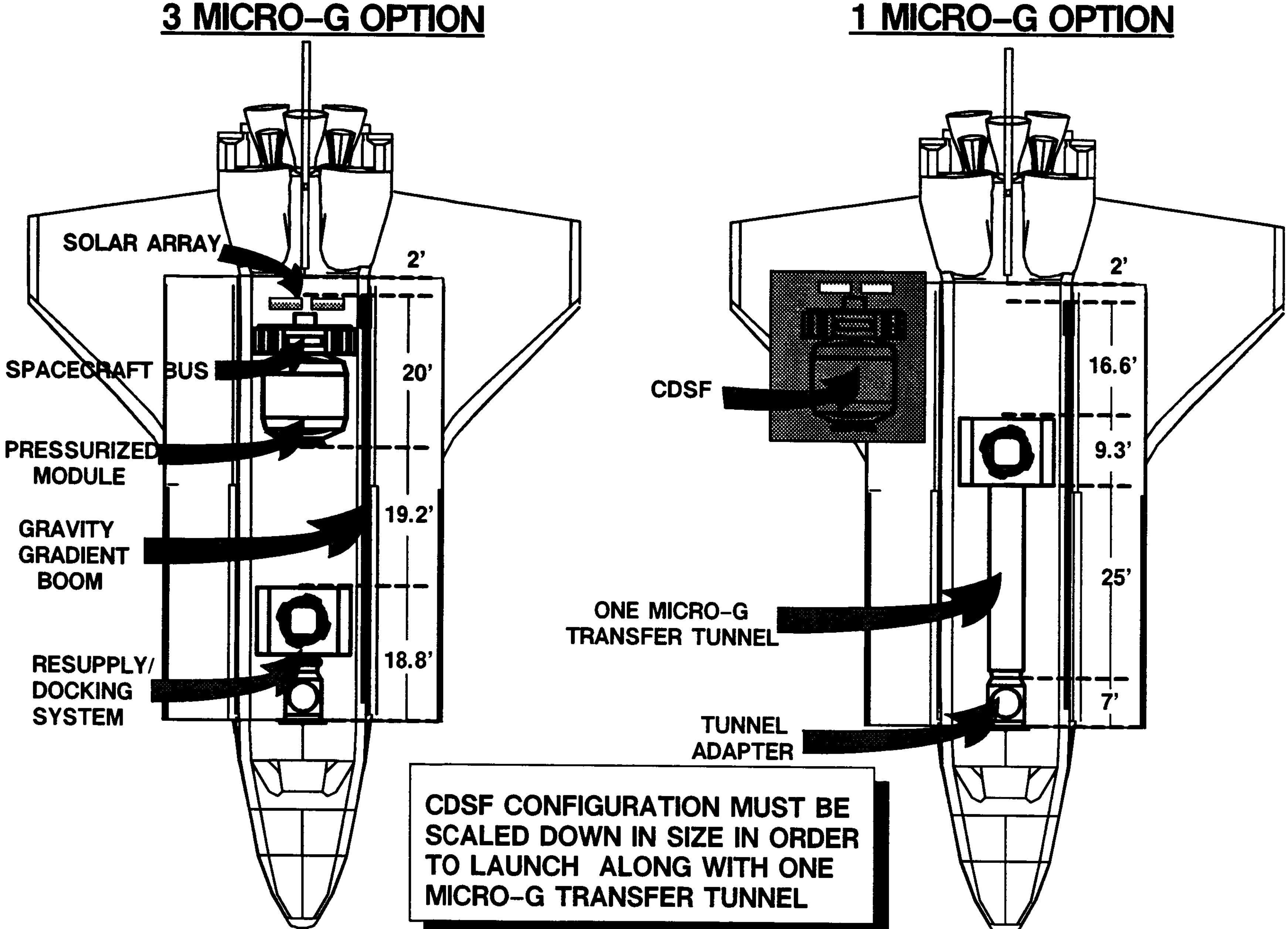


20%MATED

ONE MICRO-G TUNNEL PACKAGING

The 25 foot long one micro-g transfer tunnel cannot be packaged along with the CDSF on the deployment flight. The length of the packaged CDSF would have to be reduced by almost 6 feet in order to meet STS packaging and clearance requirements. However, on subsequent resupply and experiment missions the RDS in combination with the long one micro-g tunnel could be used along with another payload (perhaps an EDO pallet) that could be placed in the 14.6' available in the aft end of the orbiter cargo bay.

ONE MICRO-G TUNNEL OPTION



CDSF CONFIGURATION MUST BE SCALED DOWN IN SIZE IN ORDER TO LAUNCH ALONG WITH ONE MICRO-G TRANSFER TUNNEL

WEIGHT BREAKDOWNS

Complete weight breakdowns are given for the RDS and the one micro-g option transfer tunnel. The total weight of the RDS with a short tunnel is 7384 lbms which includes the STS provided tunnel adapter kit and a 15% contingency. Replacing the short tunnel with the one micro-g option transfer tunnel adds 1487 lbms to the total weight.

RESUPPLY/DOCKING SYSTEM

PRIMARY STRUCTURE	MODULE	2109	lbm
	SUPPORT SET	550	
	TRANSITION SECTION*	240	
SECONDARY STRUCTURE	FLOOR AND SUBFLOOR	81	
	RACKS	518	
	CREW HABITABILITY	136	
MECHANISMS	BERTHING ASSEMBLY	362	
ELECTRIC POWER SYSTEM	SUBSYSTEMS	184	
	HARNESS (SIGNAL POWER)	288	
	EXTERNAL UMBILICAL	92	
THERMAL CONTROL SYSTEM	ACTIVE	243	
	MULTI-LAYER INSULATION	192	
DATA MANAGEMENT SYSTEM		255	
ENVIRONMENTAL CONTROL AND LIFE SUPPORT SYSTEM	ATMOSPHERE STORAGE/CONTROL	155	
	ATMOSPHERE REVITALIZATION	370	
	FIRE PROTECTION	48	
	subtotal	6696	
	contingency (15%)	873	
TUNNEL ADAPTOR KIT (ORBITER PROVIDED)		688	
	total	7384	

*NOTE: one microg option transfer tunnel adds 1487 lbm to total

rdsweights

ONE MICROG OPTION TRANSFER TUNNEL

STRUCTURE	FORWARD ADAPTOR	66	lbm
	FORWARD FLEX SECTION	144	
	TUNNEL SEGMENT	527	
	AFT FLEX SECTION	147	
	AFT ADAPTOR	48	
SUPPORT SET		398	
MULTI-LAYER INSULATION		86	
HANDRAILS	IVA	11	
	EVA	30	
SUBSYSTEMS	LIGHTING	12	
	AIR CIRCULATION	17	
	CO_2 CONTROL	47	
	subtotal	1533	
	contingency (15%)	230	
	total	1763	

6.2.6. DEVELOPMENT SCHEDULE

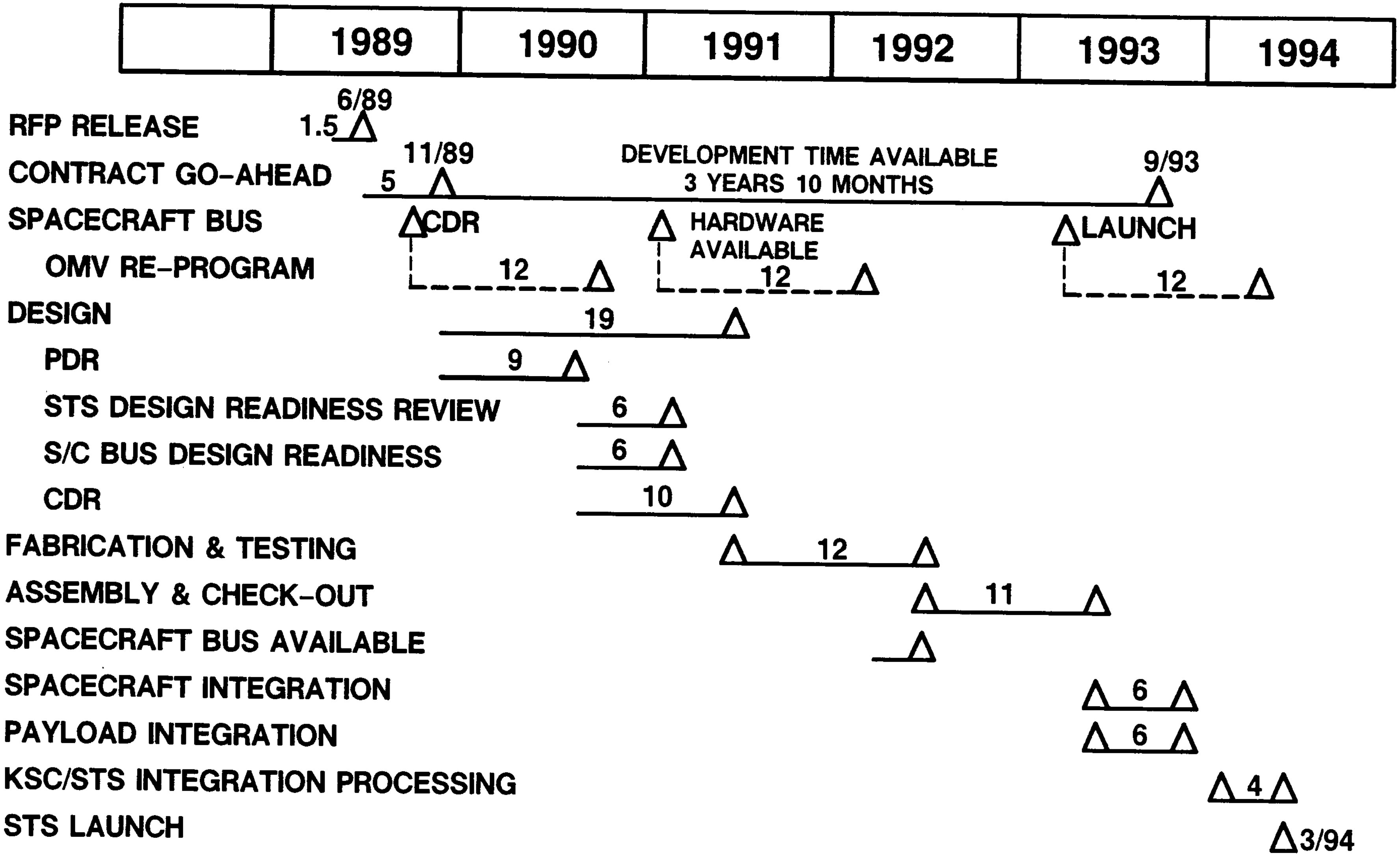
REDUCED CAPABILITY CDSF CONCEPT DEVELOPMENT SCHEDULE

The development schedule for the CDSF reduced capability concept is shown. The major development element is the experiment module and the power augmentation module. The experiment module is defined to have only 20% of the RFP baseline CDSF experiment volume capacity and the power augmentation module adds a 4 KW capability to the spacecraft power bus.

Development time is also estimated to require 3 years 10 months. While the size of the facility is smaller, interface design and development to accommodate assembly and check out of the experiment module, spacecraft bus and power augmentation module is seen to be a compensating factor.

The OMV expected slip due to current NASA funding constraints is estimated to be 12 months which is a critical consideration for implementation of this CDSF concept. Published OMV program schedules show that development is well within CDSF program needs for supplying hardware if reduced funding levels do not result in schedule impacts. However, even if OMV development is not impacted, the estimated 46 month CDSF program development time is seen to cause a 6 month delay in meeting RFP requirements for a early 1993 deployment launch.

20% CDSF DEVELOPMENT SCHEDULE



- **DEVELOPMENT TIME EXCEEDS AVAILABLE TIME BY 6 MONTHS**

FURTHER PROGRAM SLIPS IN DEVELOPMENT OF S/C HARDWARE COULD BE CRITICAL

NASA

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7.0 CDSF / NSTS INTERFACE DESCRIPTIONS

7.0 CDSF / NSTS INTERFACE DESCRIPTIONS

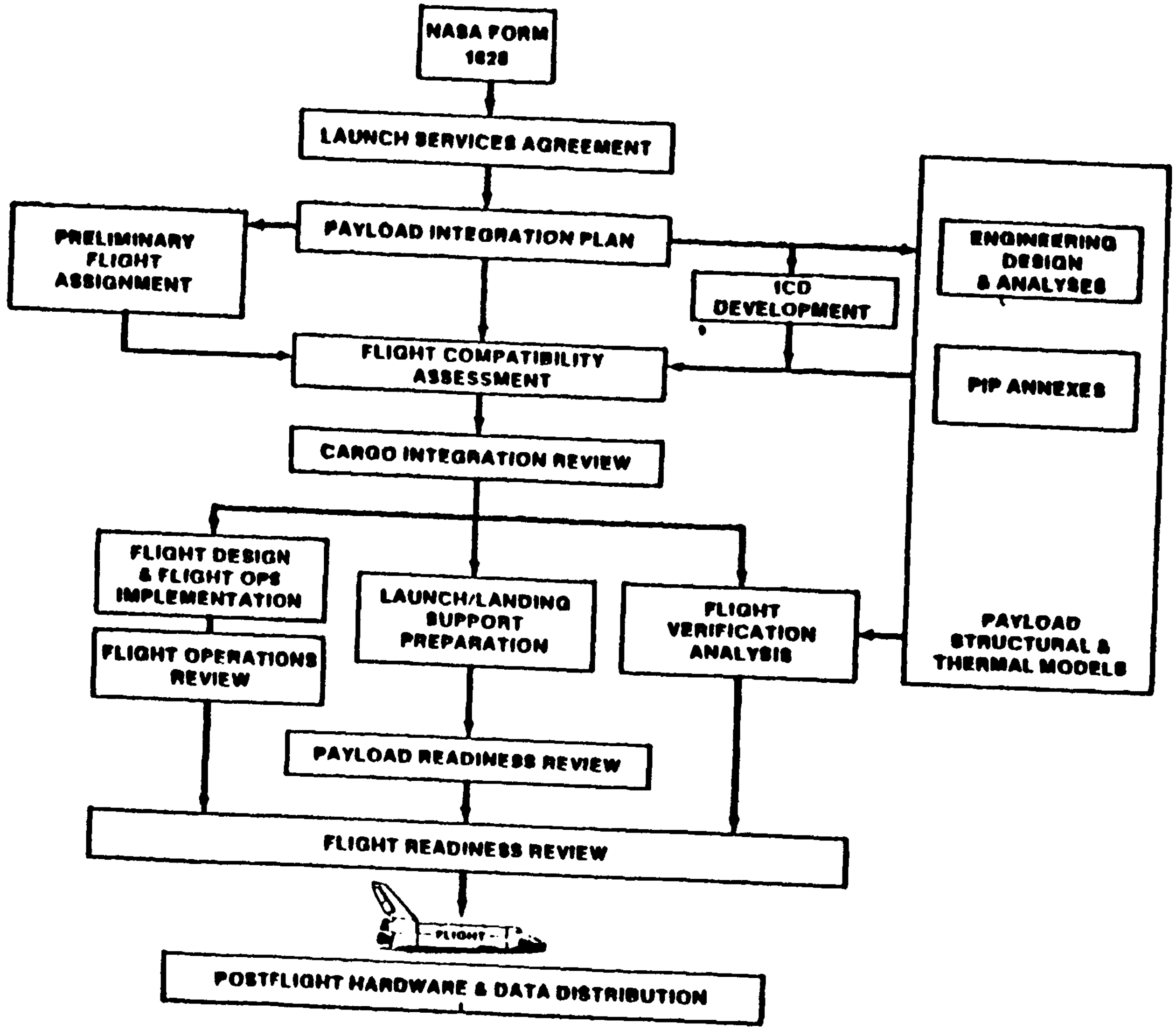
Section 7 discusses the interfaces between the CDSF and the Orbiter. Section 7.1 describes the payload integration requirements and references the appropriate documentation. Section 7.2 discusses the very important issue of safety. Section 7.3 defines operations service requirements, spanning pre-launch, flight, and post-landing phases.

Information documented in this section was provided by Mr. Thomas Shanahan of Rockwell International and was gratefully appreciated by the NASA in-house study team.

7.1. NSTS PAYLOAD INTEGRATION REQUIREMENTS

NSTS PAYLOAD INTEGRATION REQUIREMENTS

The CDSF must conform to all NSTS mechanical, electrical, avionics and environmental policies and interfaces that are contained in the shuttle/payload Standard Integration Plan for Deployable-Type Payloads, NSTS 21000-SIP-DEP, current issue and Space Shuttle System Payload Accommodations, NSTS 07700, Volume XIV, including attachment 1 (ICD-2-19001) and Appendices 1-10, current issues. The following pages describe the process necessary to conform to NSTS payload integration requirements. The payload customer shall be cognizant of the various program requirements and milestones associated with this process and be able to support all stages negotiated with the NSTS.

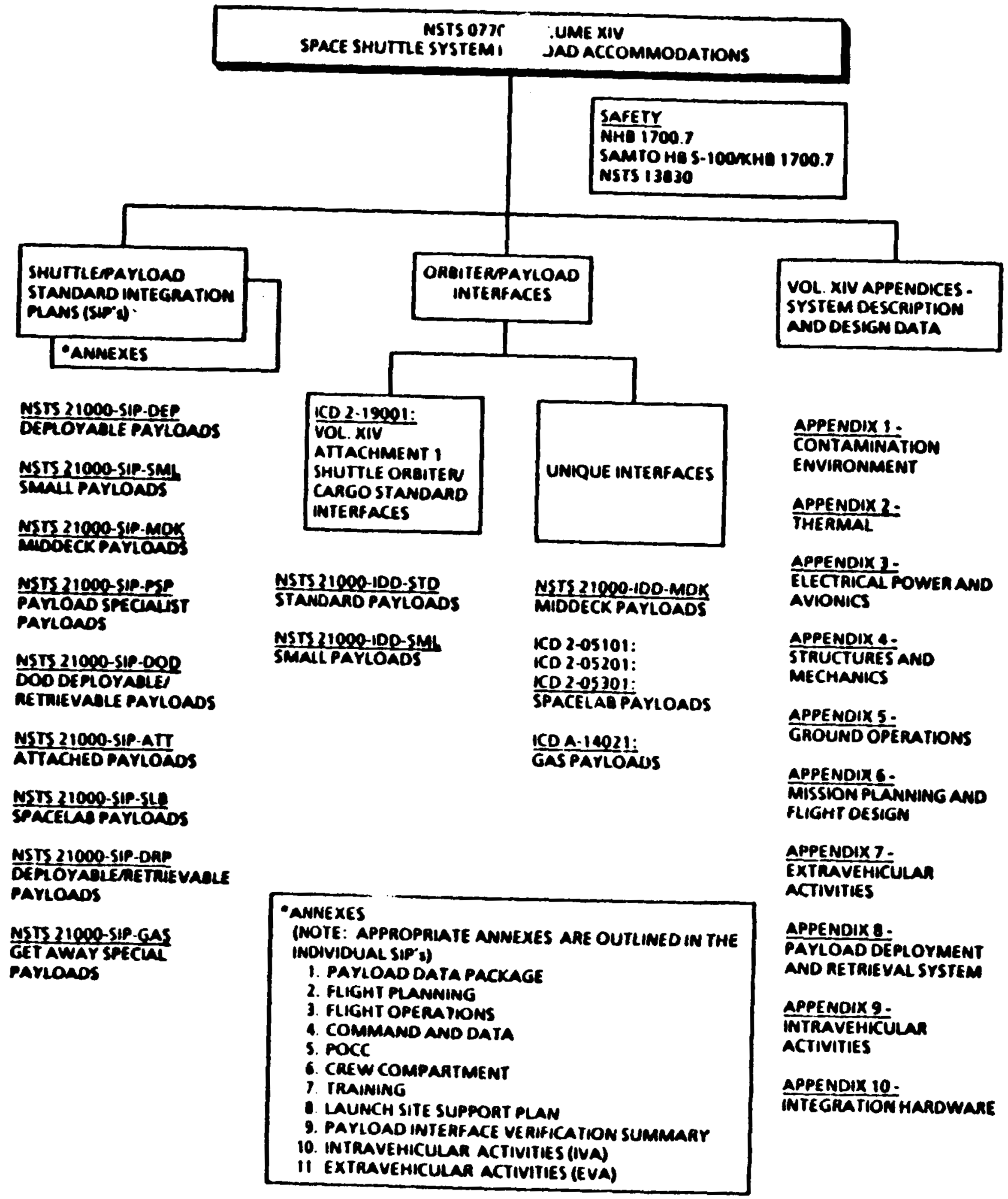


Payload integration process.

NSTS PAYLOAD INTEGRATION

NSTS payload related documentation is shown on the facing page. The payload customer shall be cognizant of this list and be able to support development of the documents required for it's payload (i.e., payload integration plan (PIP), PIP annexes, ICD's etc.). The NSTS 07700, Vol. XIV and Appendices provide necessary system description and design data associated with payload services by NSTS.

NSTS payload services are divided into standard and optional services. Optional services are subject to agreement with the NSTS. Payload customers shall demonstrate requirements for optional services. Time sharing with the Orbiter and/or other payloads may be required. Optional service charges may also be required.


NSTS 077(.UME XIV
SPACE SHUTTLE SYSTEM I .JAD ACCOMMODATIONS
SAFETY
NHB 1700.7
SAMTO HB S-100/KHB 1700.7
NSTS 13830
SHUTTLE/PAYLOAD STANDARD INTEGRATION PLANS (SIP's)
*ANNEXES
ORBITER/PAYLOAD INTERFACES
VOL. XIV APPENDICES - SYSTEM DESCRIPTION AND DESIGN DATA
NSTS 21000-SIP-DEP
DEPLOYABLE PAYLOADS
NSTS 21000-SIP-SML
SMALL PAYLOADS
NSTS 21000-SIP-MDK
MIDDECK PAYLOADS
NSTS 21000-SIP-PSP
PAYLOAD SPECIALIST PAYLOADS
NSTS 21000-SIP-DOD
DOD DEPLOYABLE/ RETRIEVABLE PAYLOADS
NSTS 21000-SIP-ATT
ATTACHED PAYLOADS
NSTS 21000-SIP-SLB
SPACELAB PAYLOADS
NSTS 21000-SIP-DRP
DEPLOYABLE/RETRIEVABLE PAYLOADS
NSTS 21000-SIP-GAS
GET AWAY SPECIAL PAYLOADS
ICD 2-19001:
VOL. XIV
ATTACHMENT 1
SHUTTLE ORBITER/ CARGO STANDARD INTERFACES
UNIQUE INTERFACES
NSTS 21000-IDD-STD
STANDARD PAYLOADS
NSTS 21000-IDD-SML
SMALL PAYLOADS
NSTS 21000-IDD-MDK
MIDDECK PAYLOADS
ICD 2-05101:
ICD 2-05201:
ICD 2-05301:
SPACELAB PAYLOADS
ICD A-14021:
GAS PAYLOADS
APPENDIX 1 -
CONTAMINATION ENVIRONMENT
APPENDIX 2 -
THERMAL
APPENDIX 3 -
ELECTRICAL POWER AND AVIONICS
APPENDIX 4 -
STRUCTURES AND MECHANICS
APPENDIX 5 -
GROUND OPERATIONS
APPENDIX 6 -
MISSION PLANNING AND FLIGHT DESIGN
APPENDIX 7 -
EXTRAVEHICULAR ACTIVITIES
APPENDIX 8 -
PAYLOAD DEPLOYMENT AND RETRIEVAL SYSTEM
APPENDIX 9 -
INTRAVEHICULAR ACTIVITIES
APPENDIX 10 -
INTEGRATION HARDWARE
*ANNEXES
(NOTE: APPROPRIATE ANNEXES ARE OUTLINED IN THE INDIVIDUAL SIP's)
1. PAYLOAD DATA PACKAGE
2. FLIGHT PLANNING
3. FLIGHT OPERATIONS
4. COMMAND AND DATA
5. POCC
6. CREW COMPARTMENT
7. TRAINING
8. LAUNCH SITE SUPPORT PLAN
9. PAYLOAD INTERFACE VERIFICATION SUMMARY
10. INTRAVEHICULAR ACTIVITIES (IVA)
11 EXTRAVEHICULAR ACTIVITIES (EVA)

SHUTTLE ORBITER SERVICES INTERFACE REQUIREMENTS

The cargo bay and aft flight deck payload interface requirements are defined in ICD-2-19001. The payload customer shall comply with these interface requirements and any deviations shall be properly negotiated and documented with the NSTS. ICD-2-19001 is generally referred to as the "core ICD". The following facing pages summarize the payload services to the avionics, electrical power, and thermal control systems.

PAYLOAD SERVICES

SERVICES				ON-ORBIT							
	STD	OPT	PRE	ASC	PD	D	D/B	FF	DES	POST	CORE ICD	COMMENTS
AVIONICS												
T-O	X		X								7.3.6	INTERFACES WITH P/L GSE OR LOCAL P/L CONTROL CENTER
SSP	X		X		X		X				13.4.2	DIRECT CREW INTERFACES IN AFD
MDM	X			X	X		X				8.2.2.	
PDI	X		X	X	X		X		X	X	8.2.1	
												UNTIL ORBITER POWERDOWN
PDI	X		X		X	X					8.3	VIA P/L INTERROGATOR
GPC DATA BUS	X			X	X	X				X	8.2.12	POST-LANDING AVAILABLE UNTIL ORBITER POWERDOWN
CCTV		X			X	X	X				8.2.8	VIDEO RECORDING/PLAYBACK B/W ON-BOARD MONITORS. NO UPLINK.
PI	X				X	X	X	X			8.3	FOR DETACHED PAYLOADS, STDN, DSN; S-BAND TO P/L
RF DIRECT FROM GROUND	X		X		X	X					8.3	S-BAND TO P/L VIA PI
S-BAND FM		X			X	X	X				8.2.6	ATTACHED P/L ONLY
KU-BAND SIGNAL PROCESSING		X			X	X	X				8.2.4	ATTACHED P/L ONLY
TIMING BUFFER		X			X	X	X				8.2.10	GMT & MET
MTU		X			X	X	X				8.2.10	TIMING FREQUENCIES
CAUTION & WARNING		X			X		X				8.2.9	AUDIO/VISUAL SYSTEM MALFUNCTION INDICATIONS
P/L SAFING		X			X	X	X				8.2.11	
P/L RECORDER	X				X	X	X	X			8.2.3	
DPP		X			X	X					13.4.3	ARMING & FIRING OF PAYLOAD PYRO'S
P/L RETENTION SAFING		X			X	X					7.6	PAYLOAD'S LATCHES CONTROL
ELEC. POWER												
DC/PRIMARY	X		X	X	X	X	X				7.3.2.1	28+/- 4 VDC 0 AWG, FUSED TO 200 AMPS ON ORBITER SIDE VIA 4
DC/T-O		X	X								7.3.6	SMCH FEEDERS FOR BATTERY TRICKLE CHG (CHARGER SUPPLIED BY P/L)
AC		X			X	X	X		X		7.4.0	115 VAC, 400 HZ, 3 AMP CIRCUIT BREAKER, AVAILABLE FROM TWO
												OUTLETS IN THE BAY

STD = STANDARD; OPT = OPTIONAL; PRE = PRELAUNCH; ASC = ASCENT; PD = PREDEPLOY; D = DEPLOY; D/B = DOCKED/BERTHED; FF = FREEFLY; DES = DESCENT; POST = POSTLANDING

PAYLOAD SERVICES

SERVICES					ON-ORBIT							
	STD	OPT	PRE	ASC	PD	D	D/B	FF	DES	POST	CORE ICD	COMMENTS
PHYSICAL I/F												
PAYLOAD BAY												
THERMAL/DYN. ENV.	X		X	X	X	X	X		X	X	3.1	MAXIMUM LENGTH - TBD; MAXIMUM DIAMETER - 15 FT
CAMERA/LIGHTING	X				X	X	X	X			3.1	
ELECTRICAL UMBILICALS		X	X	X	X	X			X	X	TBD	REQUIREMENTS NOT IN CORE
MECH/ELEC/COOLING I/F	X		X	X	X	X	X		X	X	3.3	REDUCED BASED ON MAXIMUM BAY LENGTH
AFT FLIGHT DECK	X	X	X	X	X	X	X	X	X	X	3.2	
DEFLECTION/LIMIT LOAD/												
C.G. LIMITS	X		X	X	X	X	X		X	X	4	
PASSIVE THERMAL CONTROL	X		X		X	X	X		X	X	6.1	
ACTIVE THERMAL CONTROL												
GAS PURGE	X		X							X	6.2	AIR OR GN2
LIQUID COOLING		X	X								6.2	WATER OR FREON, NON-DEPLOYABLE PAYLOADS
INDUCED ENVIRONMENT												
BAY PARTICULATE &												
GAS-ORBITER & PAYLOAD	X		X	X	X	X	X	X	X	X	10.6	
OMS/RCS PLUME DATA	X				X	X	X	X			11.2	
PAYLOAD DEPLOYMENT SYS.												
RMS		X			X	X	X				14	
SPDS		X			X	X					TBD	REQUIREMENTS IN WORK
DOCKING/BERTHING SYSTEM		X					X				TBD	SYSTEM UNDER DEVELOPMENT - NO REQUIREMENT DEFINED

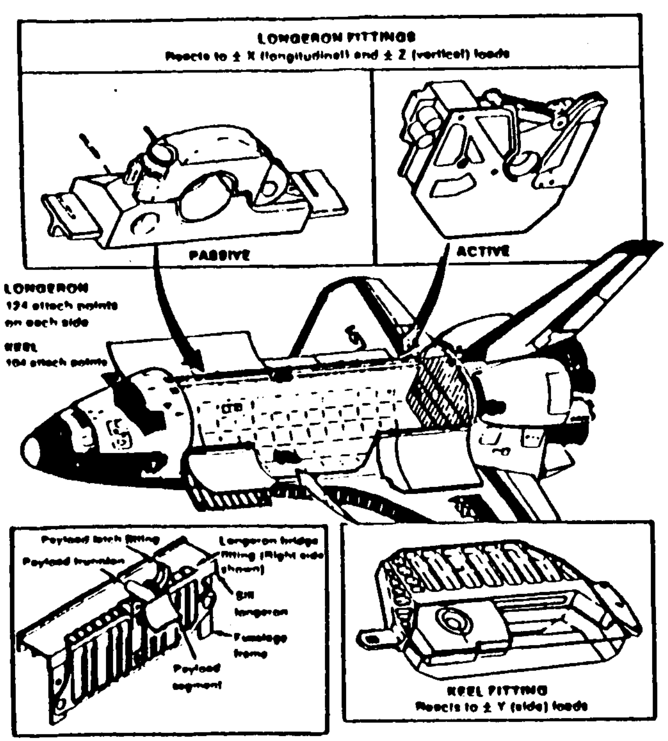
STD = STANDARD; OPT = OPTIONAL; PRE = PRELAUNCH; ASC = ASCENT; PD = PREDEPLOY; D = DEPLOY; D/B = DOCKED/BERTHED; FF = FREEFLY; DES = DESCENT; POST = POST LANDING

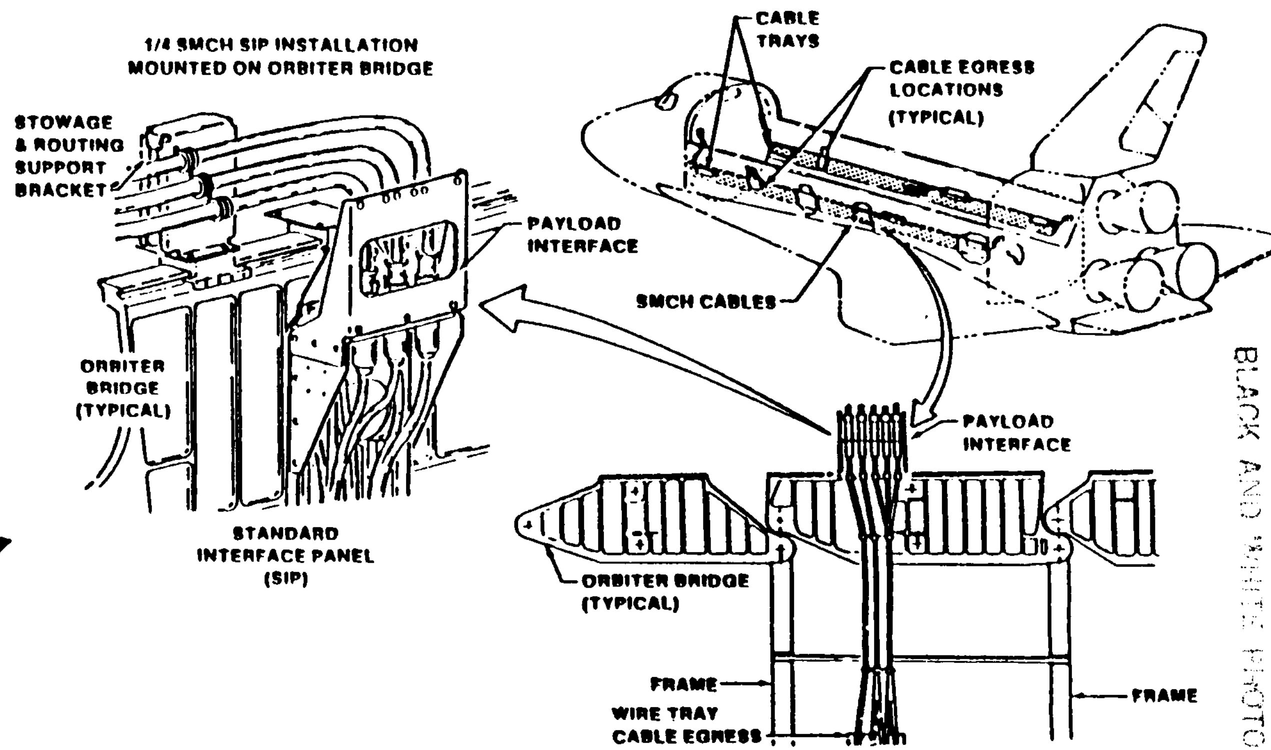
STRUCTURAL / AVIONICS PAYLOAD BAY INTERFACES

The following pages describe the structural (longeron and keel fittings), thermal, electronic, and avionics interfaces that the CDSF will use for interfacing with the NSTS. Also illustrated is the location of the standard mixed cargo harness (SMCH).

STRUCTURAL/AVIONICS PAYLOAD BAY INTERFACES

LONGERON FITTINGS ARE MOUNTED ON BRIDGES





SMCH CABLES CARRY ALL STANDARD AVIONICS AND POWER INTERFACES.

LIQUID COOLING INTERFACE IS MOUNTED ON THE SIDE OF THE SIP CLOSEST TO THE PAYLOAD

THERMAL CONTROL

- PASSIVE
  - ACCOMPLISHED BY CONTROLLING ORBITER ATTITUDE WHILE ON ORBIT
- ACTIVE
  - ACCOMPLISHED VIA GAS PURGE OR LIQUID COOLING
    - GAS PURGE IS USED FOR PRE-LAUNCH OPERATIONS
    - LIQUID COOLING IS AVAILABLE FOR NON-DEPLOYABLE PAYLOADS AS AN OPTIONAL SERVICE FOR ON-ORBIT OPERATIONS

AVIONICS

- THE ORBITER AVIONICS SYSTEM PROVIDES SUPPORT FOR PAYLOAD COMMAND AND DATA INTERFACES

  - SUPPORT IS PROVIDED FOR TRANSFERRING AND/OR RELAYING COMMAND DATA FROM NASA STDN AND TDRSS TO ATTACHED & DETACHED PAYLOADS & FOR RECEIVING TELEMETRY DATA FROM PAYLOADS & RELAYING TO ORBITER OR PAYLOAD GROUND STATIONS

SOFTWARE

- THE ORBITER SOFTWARE INTERFACES INCLUDE THE PAYLOAD DATA INTERLEAVER (PDI), MULTIPLEXER/ DEMULTIPLEXER (MDM), PAYLOAD SIGNAL PROCESSOR (PSP) & PAYLOAD DATA BUS

  - AS AN OPTIONAL SERVICE, ORBITER STATE VECTOR/ ATTITUDE DATA CAN BE TRANSFERRED TO THE PAYLOAD VIA PSP, MDM, OR DATA BUS

ELECTRICAL POWER

- ELECTRICAL POWER IS AVAILABLE FOR PAYLOAD USE DURING ALL MISSION PHASES

  - ACTUAL POWER AVAILABLE TO A PAYLOAD AT ANY ONE TIME IS A FUNCTION OF MANY VARIABLES, WHICH INCLUDE:

    PAYLOAD MANIFEST, MISSION DURATION, MISSION UNIQUE ATTITUDE REQUIREMENTS, ORBITER POWER ALLOCATION, PAYLOAD POWER FEEDER ALLOCATION

- ELECTRICAL ENERGY

  - STANDARD ALLOCATION FOR A PAYLOAD IS 12.5 KWH

AVIONICS SERVICES CHARACTERISTICS

- PAYLOAD DATA INTERLEAVER (PDI)
    - INTERFACE FOR ACQUIRING ASYNCHRONOUS PULSE CODE MODULATION (PCM) TELEMETRY FROM ATTACHED AND DETACHED PAYLOADS
        - TOTAL INPUT PORTS IS 5 FOR ATTACHED PAYLOADS AND 1 FOR DETACHED PAYLOADS
            - 1 INPUT PORT PER STANDARD PAYLOAD
        - ON-ORBIT IS NOMINALLY LIMITED TO 64 KBPS
        - NRZ AND BI-PHASE DATA CODES ARE AVAILABLE
- PAYLOAD SIGNAL PROCESSING (PSP)
    - TRANSMITS SERIAL DIGITAL COMMANDS TO ONE DETACHED PAYLOAD VIA PAYLOAD INTERROGATOR OR ONE ATTACHED PAYLOAD SELECTED BY THE CREW OR GROUND STATION.
        - 9 DISCRETE DATA RATES UP TO 2000 BITS/SECOND
        - 3 NRZ DATA CODES AVAILABLE

- ORBITER MULTIPLEXER/DEMULTIPLEXER (MDM)
  - ACTS AS DATA ACQUISITION, DISTRIBUTION AND SIGNAL CONDITIONING UNIT OF DIGITAL AND ANALOG SIGNALS
    - 16 DISCRETE HIGH-LEVEL (DOH), 0-28 VDC
    - 32 DISCRETE LOW-LEVEL (DIH), 0-5 VDC
    - 32 DISCRETE LOW-LEVEL (DIL), 0-5 VDC
    - 8 ANALOG DIFFERENTIAL (AID), 0-5 VDC
    - ADDITIONAL ANALOG & DISCRETE COMMANDS/INPUTS AVAILABLE
- PAYLOAD INTERROGATOR (PI)
  - PROVIDES COMMUNICATIONS (COMMANDS AND DISPLAY) BETWEEN THE ORBITER AND DETACHED PAYLOADS
    - S-BAND RF LINK COMPATIBLE W/STDN AND DSN
    - 9 DISCRETE DATA RATES UP TO 2000 BITS/SECOND
    - NRZ AND BI-PHASE DATA CODES

PAYLOAD DATA BUS

- PROVIDES COMPATIBLE INTERFACE MATCHING, ISOLATION AND FAULT PROTECTION
  - ALLOWS PAYLOAD BUS TERMINAL UNIT (BTU) AND GPC TO OPERATE AS DIGITAL TRANSMISSION SYSTEM
    - GN & C DATA; DISCRETE PULSED DISCRETE, ANALOG, SERIAL INPUT/OUTPUT

STANDARD SWITCH PANEL (SSP)

- PROVIDES SWITCH CLOSURE AND/OR 28 VDC CMDs AND STATUS INDICATORS IN THE AFT FLIGHT DECK (AFD)
  - PAYLOAD OPERATIONS AND STATUS MONITORING
  - OVERLAY PANELS PROVIDED TO IDENTIFY PAYLOAD FUNCTIONS
  - 24 SWITCHES OPERATED BY CREW IN ORBIT
  - 24 STATUS INDICATORS (TALKBACKs)

TIMING

- GMT & MET AVAILABLE
- TIMING FREQUENCIES OPTIONAL

RECORDING

- VIA ORBITER PAYLOAD RECORDER
  - 3 PARALLEL TAPE RECORDING CHANNELS (ONE ANALOG, TWO DIGITAL)
  - 10 MINUTES AVAILABLE DURING ASCENT/DESCENT, PAYLOAD DEPLOYMENT
  - ALL PAYLOADS MAY RECORD DATA WHEN RECORDER IS OPERATING
- ORBITER OPERATIONAL RECORDER
  - ORBITER PCM TELEMETRY DATA (INCLUDES PDI DATA) DURING PORTIONS OF FLIGHT
  - PAYLOAD USE DEPENDS ON ORBITER DATA REQUIREMENT
  - PLAYBACK DATA AVAILABLE IN ORIGINAL FORMAT

ON-BOARD SOFTWARE

- ON-BOARD INITIATED SINGLE COMMANDS
  - 40 SINGLE COMMANDS, AS A STANDARD, THROUGH (SM) GPC
    - CAN BE ISSUED TO A PAYLOAD BTU, ORBITER MDM, THE PSP OR THE PI
- ON-BOARD DATA PROCESSING
  - 40 PARAMETERS AS A STANDARD
    - DISCRETE OR ANALOG
    - DATA ACQUISITION VIA PDI, ORBITER PAYLOAD MDM, OR PAYLOAD BTU
    - DATA DISPLAYED TO CREW, TRANSMITTED TO MCC-H MAY BE FORWARDED TO CUSTOMER POCC

OPTIONAL SERVICE

- 20 COMMANDS OR 20 DATA PARAMETERS

OPTIONAL UPLINK COMMANDS VIA KU-BAND FORWARD LINK

- 128 KPBS COMMAND DATA TO PAYLOADS
- TIME-SHARED W/ORBITER UPLINK TEXT & GRAPHICS

OPTIONAL UPLINK COMMANDS VIA ORBITER OPERATIONAL UPLINK

- MCC-H STORES, GENERATES AND TRANSMIT PAYLOAD CMDs VIA THE ORBITER OPERATIONAL UPLINK & DATA PROCESSING SYSTEM
- TRANSFERRED TO PAYLOAD VIA PSP, THE MDM, OR PAYLOAD DATA BUS

INTERFACE CABLE HARNESSES

- STANDARD ELECTRICAL POWER/AVIONICS SERVICES ARE PROVIDED VIA THE STANDARD MIXED CARGO HARNESS (SMCH), DIVIDED INTO FOUR SECTIONS IN THE BAY FOR FOUR SEPARATE PAYLOADS
  - NORMAL INTERFACE FOR ATTACHED PAYLOADS IS VIA STANDARD INTERFACE PANELS (SIP'S) ON THE PORT & STARBOARD SIDES
  - DEPLOYABLE PAYLOADS MAY USE THE SHUTTLE UMBILICAL RETRACTION SYSTEM (SURS) ON THE PORT & STARBOARD SIDE, OR THE REMOTELY OPERATED ELECTRICAL UMBILICAL (ROEU) ON THE PORT SIDE
    - BOTH UMBILICAL SYSTEMS PROVIDE ONLY 1/4 OF SMCH OF THE TOTAL POWER/AVIONICS SERVICES IN THE BAY

PAYLOAD DEPLOYMENT SYSTEMS

- REMOTE MANIPULATOR SYSTEM
    - ORBITER PROVIDED SYSTEM FOR DEPLOYMENT & RETRIEVAL
    - MAXIMUM ALLOWABLE PAYLOAD ENVELOPE IS CONSTRAINED BY RMS OPERATIONS

7.2. SAFETY ISSUES

SAFETY ISSUES

Design and operations of the CDSF will comply with the requirements of NHB 1700-7B and KHB 1700.7. The CDSF will meet these requirements at the launch/landing sites and during flight operations, orbital operations and ferry flights. The following pages highlight significant safety issues.

SAFETY ISSUES
CDSF AS A TENDED FACILITY

- LOSS OF HABITABLE ENVIRONMENT
  - FACILITY SHARES ORBITER CABIN ENVIRONMENT
  - TOXICITY MONITORING/READOUT REQUIRED
  - MATERIAL ASSESSMENT TO NHB 8060.1 FOR FLAMMABILITY, ODOR AND OUTGASSING
  - ALL HATCHES MUST BE ABLE TO BE CLOSED AT ALL TIMES FOR COMPARTMENTATION SAFETY

- ORBITER ABILITY TO SEPARATE FROM CDSF/RETURN TO EARTH
  - SEPARATION MUST BE CONTROLLED BY INDEPENDENT PRIMARY AND BACK-UP MODES. THE COMBINATION OF PRIMARY AND BACK-UP MUST BE TWO FAILURE TOLERANT
  - NO PART OF CDSF MAY PREVENT CLOSURE OF THE PAYLOAD BAY DOORS AT FAYING SURFACE AFTER CDSF SEPARATION

- FIRE/EXPLOSION
  - MATERIAL FLAMMABILITY SCREENING PER NHB 8060.1
  - PRESSURE VESSELS TO DEMONSTRATE QUALIFICATION AT TWO TIMES EXPECTED PRESSURIZATION CYCLES PER MIL-STD-1522

SAFETY ISSUES
CDSF AS A TENDED FACILITY (CONT)

- INJURY/ILLNESS
  - COMPLY WITH PROVIDED PARAGRAPH 220 "MAN-TENDED PAYLOADS" OF NHB 1700.7B WITH DESIGN GOALS AS SPECIFIED IN NASA-STD-3000 "MAN-SYSTEM INTEGRATION STANDARDS"
  - HAZARDOUS PROCEDURES OR HAZARD GENERATING PROCEDURES SCREENED ON A CASE-BY-CASE BASIS
- COLLISION/IMPACT
  - CDSF ATTITUDE CONTROL MUST BE ABLE TO BE SAFED AND VERIFIED BY ORBITER CREW
  - ORBITER CREW OVERRIDE OF CRITICAL GROUND CONTROLS DESIRED
- CORROSION/CONTAMINATION
  - EXTERNAL EFFLUENTS MUST BE SAFED PRIOR TO ORBITER HOOK-UP
- HAZARDOUS COMMANDS FROM GROUND CONTROLLING STATIONS MUST BE SINGLE OR TWO FAULT TOLERANT PER NHB 1700.7A DEFINITIONS
  - CDSF AS AN STS PAYLOAD MUST COMPLY WITH 1700.7A AND KHB 1700.7A AS IMPLEMENTED BY JSC 13830A

7.3. PRE–LAUNCH, FLIGHT, AND POST–LANDING INTERFACE AND OPERATIONS SERVICES REQUIRED

PRE-LAUNCH SERVICES

The following pages describe the pre-launch operations and pre-launch services required for processing a CDSF for a Space Shuttle launch. Optional services are needed where applicable.

PRE-LAUNCH SERVICES

- HORIZONTAL OR VERTICAL PROCESSING IS AVAILABLE FOR CHECKOUT AND INSTALLATION
- PAYLOAD BAY SERVICES
  - 28 VDC POWER
  - CLEAN AIR OR GN2 PURGE FOR THERMAL CONTROL & CONTAMINATION CONTROL
  - COMMAND & CONTROL THROUGH ORBITER SYSTEMS OR T-0 UMBILICAL
- THE PAYLOAD CAN PROVIDE GSE DRAG ON CABLES FOR PAYLOAD CHECKOUT PRIOR TO PAYLOAD BAY DOOR CLOSURE

PRE-LAUNCH SERVICES (CONT'D)

- LAUNCH AND LANDING SITE ICD
  - ICD-2-0A002, SPACE SHUTTLE LAUNCH PAD 4 PLATFORM
  - JSC 16719 VOL I, FLIGHT PROGRAM REQUIREMENTS DOCUMENT (PRD/PSP/OR) STS OPERATIONS FOR KSC LAUNCHES

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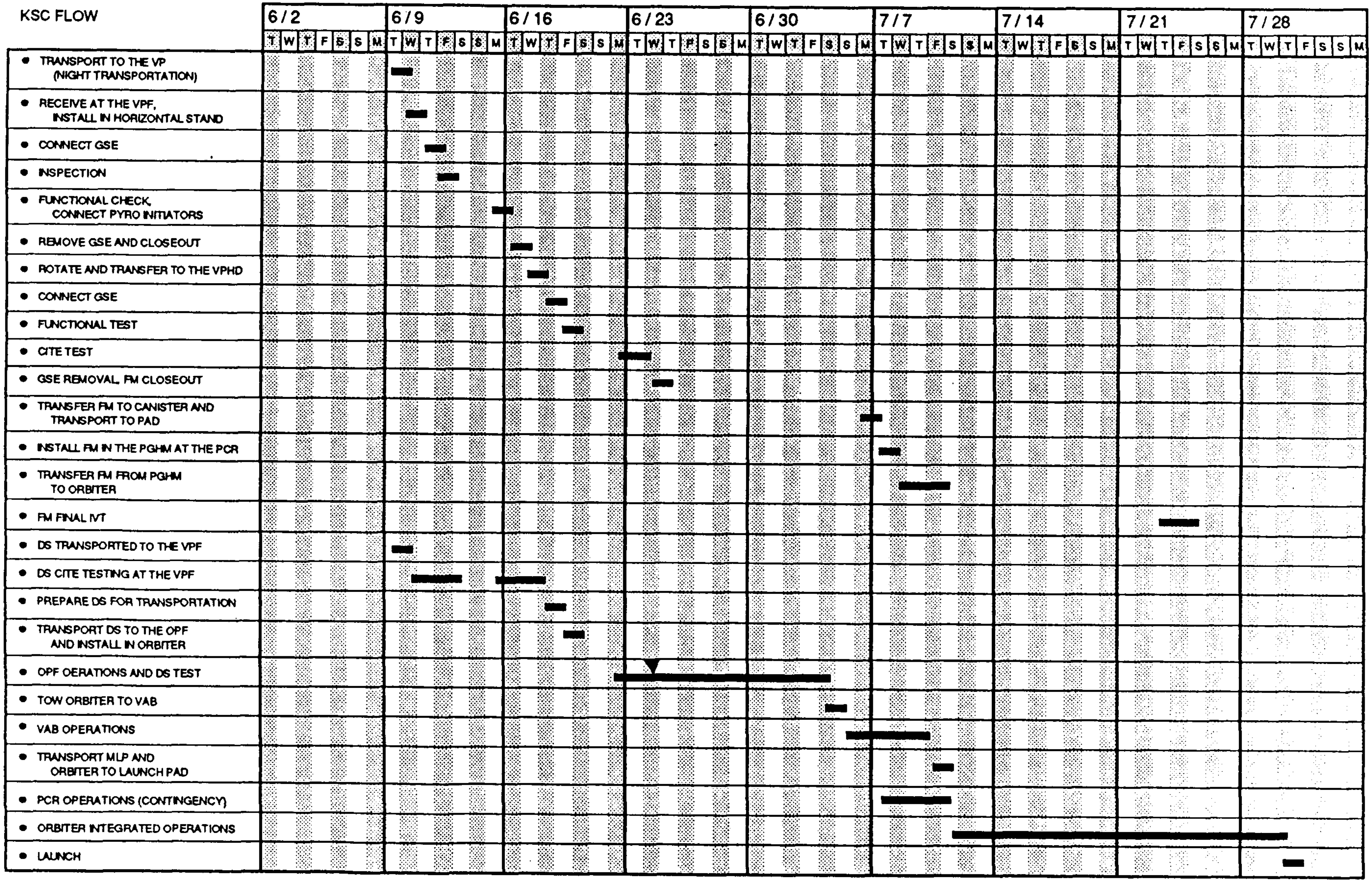
KSC PROCESSING SCHEDULE

An example of the Kennedy Space Center Processing Schedule required for a CDSF Space Shuttle launch is shown.

The NASA in-house study team is grateful to Mr. Al Louviere, Space Industries, Inc., for providing information derived for the Industrial Space Facility (ISF) concept Space Shuttle launch process. It provides the basis for the CDSF processing flow concept described in this section.

KSC PROCESSING SCHEDULE



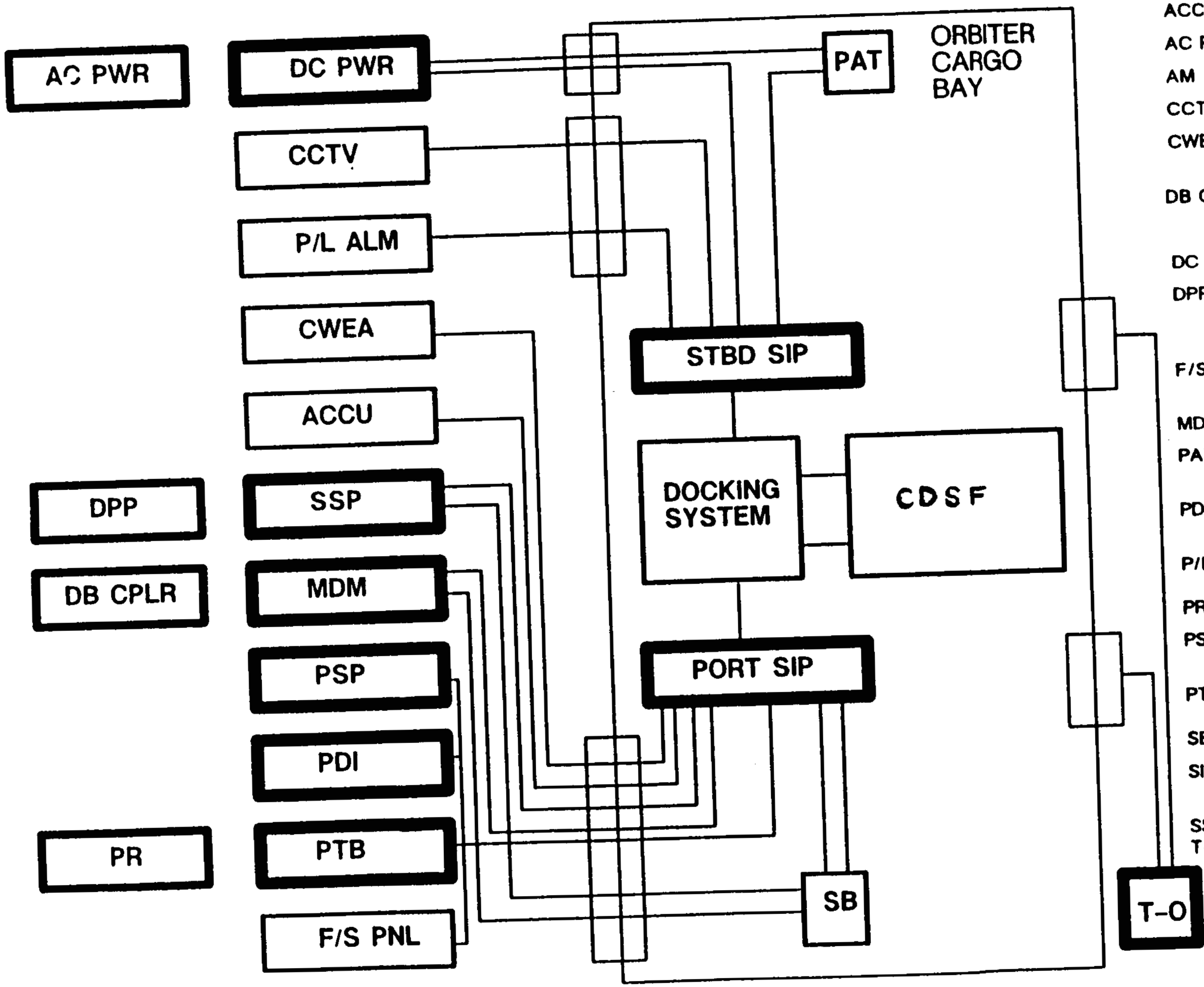
STS SERVICE INTERFACES AND CHARACTERISTICS

The following pages describe the STS services and interface characteristics that the CDSF requires for pre-launch processing, launch ascent, and in-flight deployment. Descent and post-flight descriptions are applicable to the return of the resupply module or return of the CDSF itself.

STS SERVICES ALLOCATION

	KSC Processing	Pre-Launch		Ascent	Payload Deployment			Descent	Post Flight
		Doors Open	Doors Close		Pre	Berth	Post		
Electrical Power (KW)	2.35	2.35	1.0	1.0	2.35	3.5 NASA* 7.0 SIP	1.0	1.0	1.0
Comm. command (kbps)	2 PI 2 PSP	2 T-O 2 PI 2 PSP	2 T-O 2 PSP	0	2 PSP 2 PI	2 PSP 2 PI	2 PI	0	0
Data-telemetry (kbps)	4,16,48 PDI 16 PI	16 PI 4,16,48 PDI 4,16,48T-O	4,16,48T-O 4,16,48 PDI	4 PDI	16 PI 16,48PDI	16 PI 16,48 PDI	16 PI	-	-
C&W	SSP,MDM, C3A5, safing sw, killpower CWEA	SSP,MDM, C3A5, killpower, CWEA	SSP,MDM, C3A5, CWEA	C3A5, CWEA MDM(tlm)	SSP,MDM, C3A5, killpower, CWEA	SSP,MDM, C3A5, killpower, CWEA	SSP,MDM, C3A5, killpower, CWEA	C3A5, CWEA, MDM(tlm)	SSP,MDM, C3A5, killpower, CWEA
Thermal	2.35	2.35	1.0		2.35	3.5 NASA* 7.0 SIP	1.0		1.0
Mechanical		DS/Orbiter adapter, 10 pt supports ROEU							
Special	ACCU CCTV	ACCU CCTV			ACCU CCTV	ACCU CCTV	ACCU CCTV		ACCU
Cargo Bay Weight (lb)				38,330				5,840	
RMS Handling Weight (lb)					32,490		32,490		
Crew Interfaces					RMS	TBD	RMS		

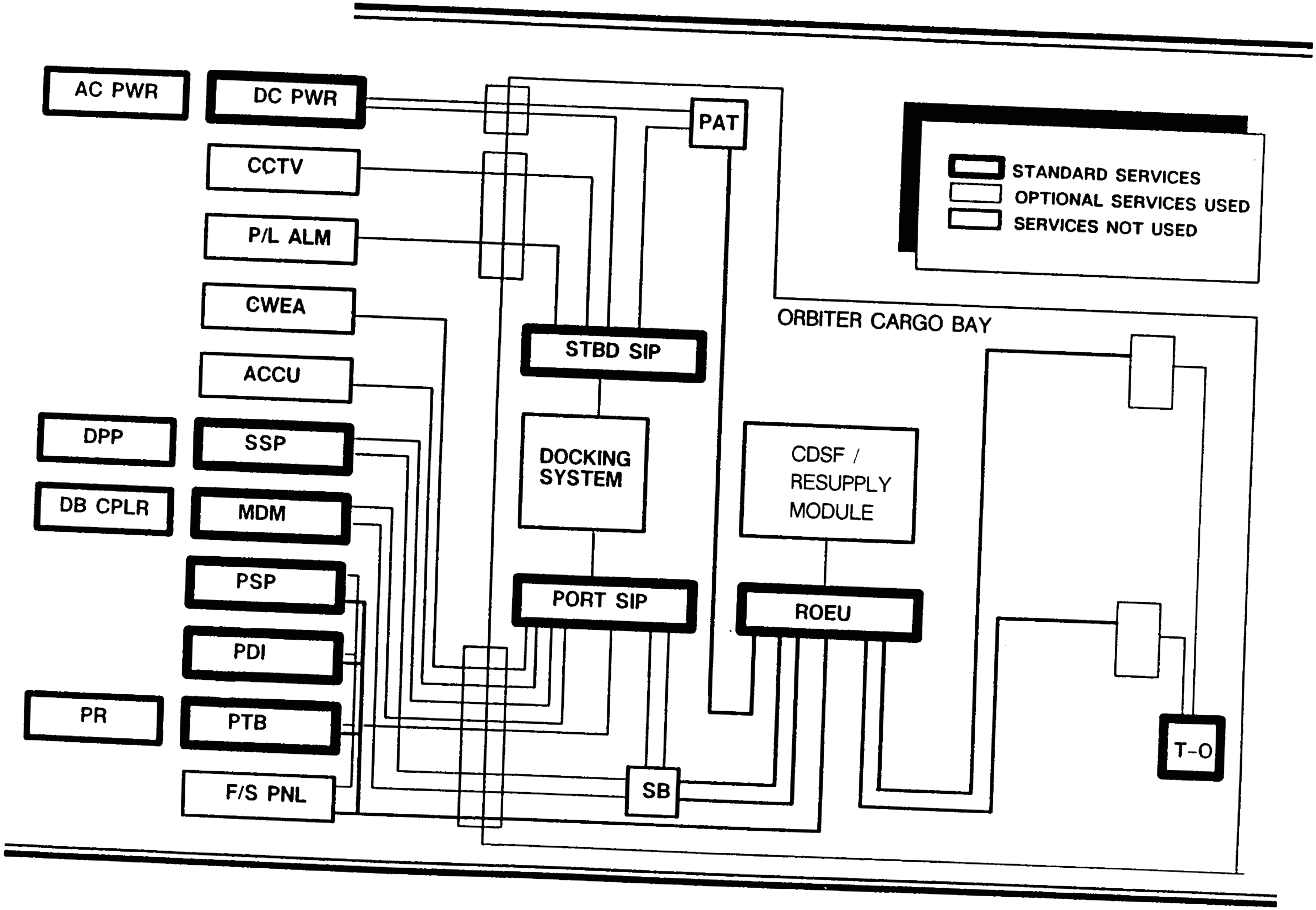
ORBITER SERVICES - BERTHED



ACCU	AUDIO CENTRAL CONTROL UNIT
AC PWR	AC POWER
AM	AUXILIARY MODULE
CCTV	CLOSED CIRCUIT TELEVISION
CWEA	CAUTION AND WARNING ELECTRONIC ASSEMBLY
DB CPLR	DATA BUS COUPLER TO GENERAL PURPOSE COMPUTER
DC PWR	DC POWER
DPP	DEPLOYMENT AND POINTING PANEL
F/S PNL	FIRE AND SMOKE PANEL
MDM	MULTIPLEXER / DEMULTIPLEXER
PAT	POWER ACCOMODATION TERMINAL
PDI	PAYLOAD DATA INTERLEAVER
P/L ALM	PAYLOAD MASTER ALARM
PR	PAYLOAD RECORDER
PSP	PAYLOAD SIGNAL PROCESSOR
PTB	PAYLOAD TIMING BUFFER
SB	SPLIT BOX
SIP	STANDARD INTERFACE PANEL
SSP	STANDARD SWITCH PANEL
T-O	T-O UMBILICAL

STANDARD SERVICES
OPTIONAL SERVICES USED
SERVICES NOT USED

ORBITER SERVICES - STOWED



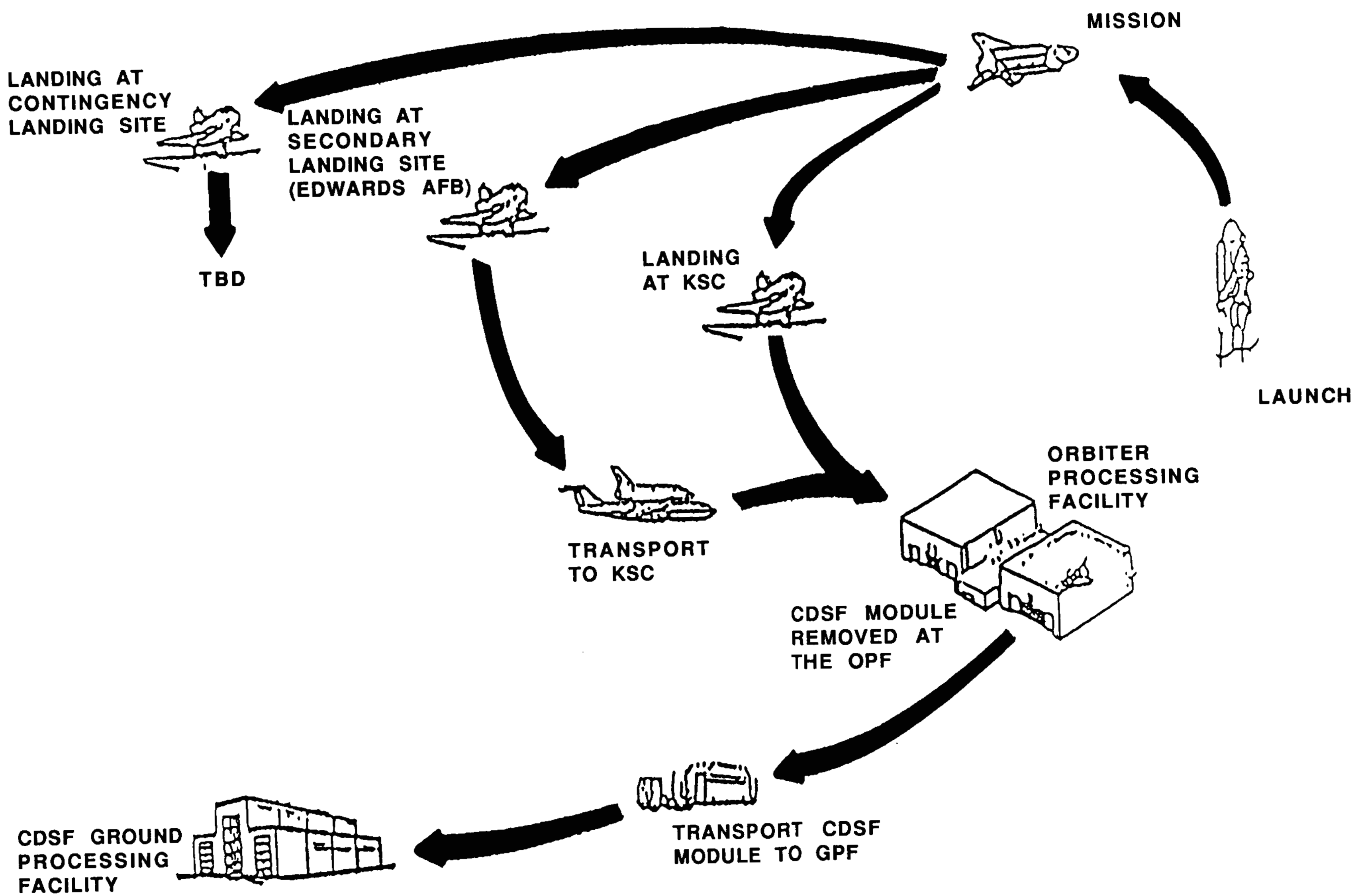
POST LANDING SERVICES

The following pages describe post flight services to be provided by the STS for CDSF resupply or retrieval missions.

POST-LANDING SERVICES

- AN AIR PURGE OF THE PAYLOAD BAY IS PROVIDED WITHIN 45 MINUTES OF LANDING AT KSC
- HORIZONTAL REMOVAL OF PAYLOADS IS IN THE OPF AFTER A LANDING AT KSC
- REFERENCE SPACE SHUTTLE SYSTEM PAYLOAD ACCOMMODATIONS, VOLUME XIV, APPENDIX 5 FOR FURTHER INFORMATION

CDSF OPERATIONS FLOW - POST - FLGHT

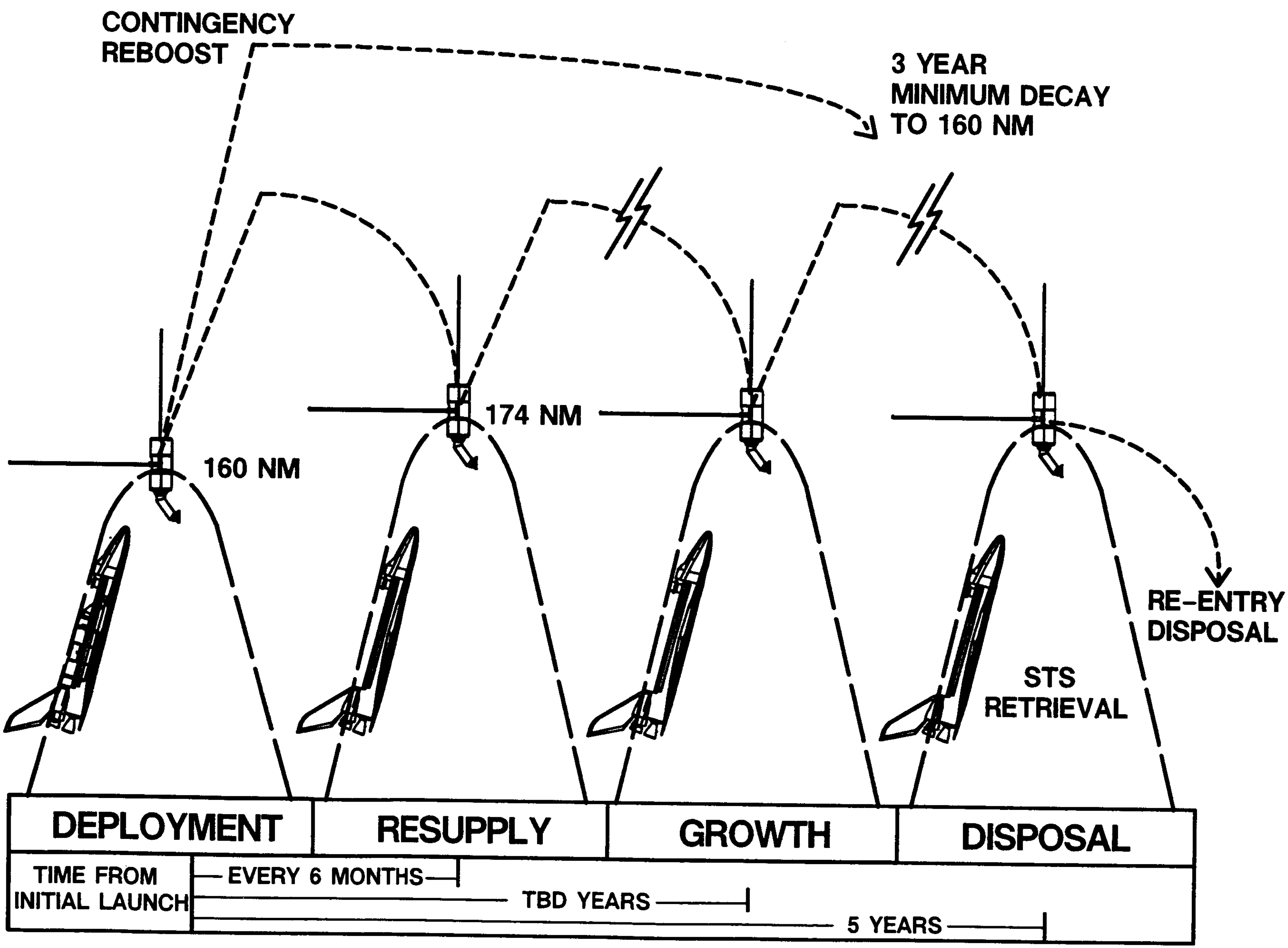


8.0. FLIGHT OPERATIONS SCENARIOS

FLIGHT OPERATIONS

The following figures describe CDSF flight operations. CDSF concept #1 is deployed from a circular orbit of 160 n.mi. with an inclination of 28.45 degrees. CDSF concept #2 is deployed from a circular orbit of 175 n.mi. (an STS optional service) with an inclination of 28.45 degrees. CDSF concept #1 has a servicing altitude of 174 n.mi. and CDSF concept #2 has a servicing altitude of 202 n.mi. with servicing intervals of 6 months for each concept. Both concepts are capable of maintaining at least a 3 year orbital lifetime without any STS servicing during the operational life of the CDSF. Growth for CDSF concept #1 is achieved by attaching another facility to the orbiting facility. Growth for concept #2 is achieved by deploying multiple facilities. The preferred method of disposal for both CDSF concepts is recovery by the STS.

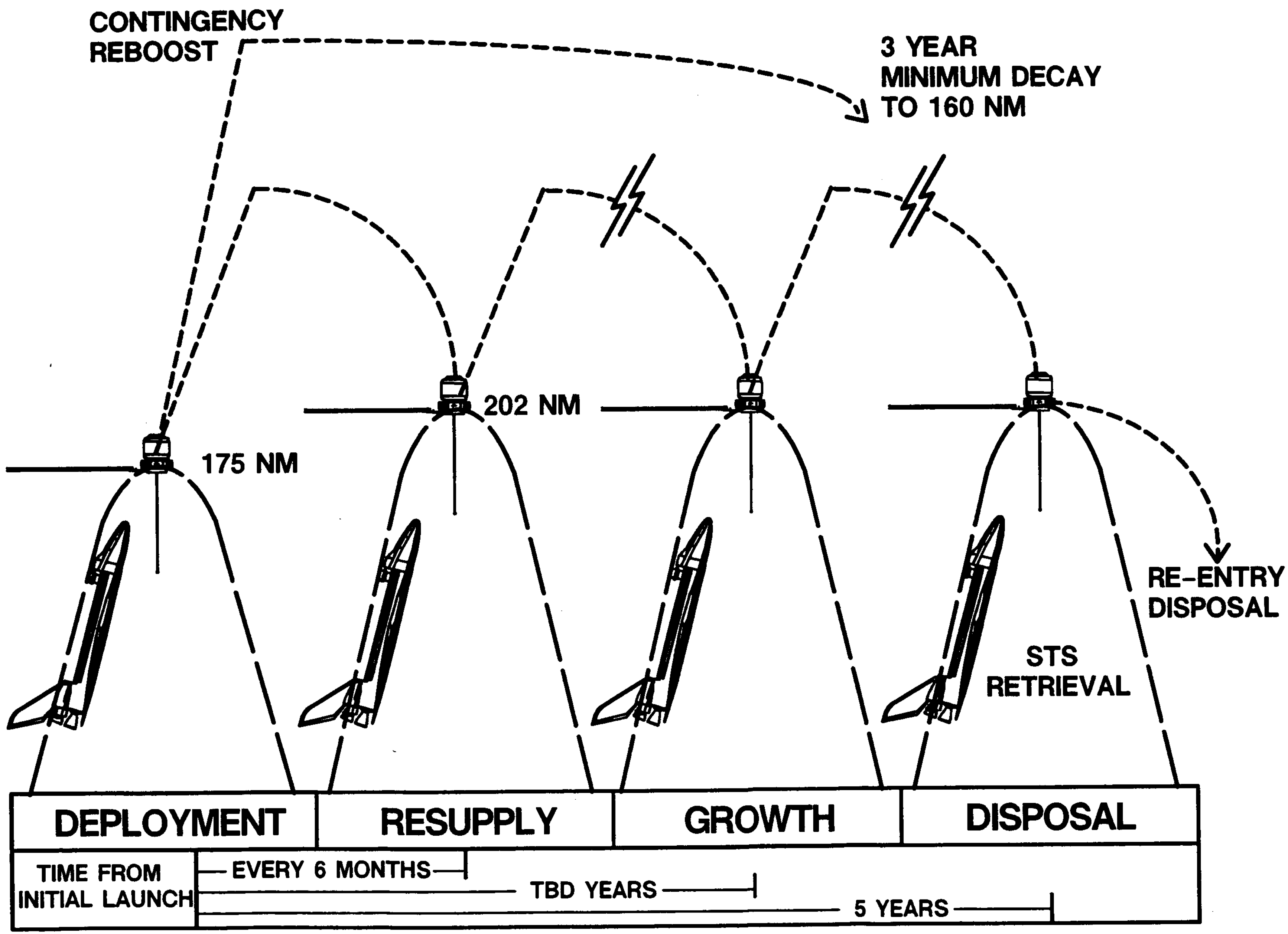
CDSF CONCEPT #1 FLIGHT INCREMENT PROFILE



C-6

FIP100

CDSF CONCEPT #2 FLIGHT INCREMENT PROFILE



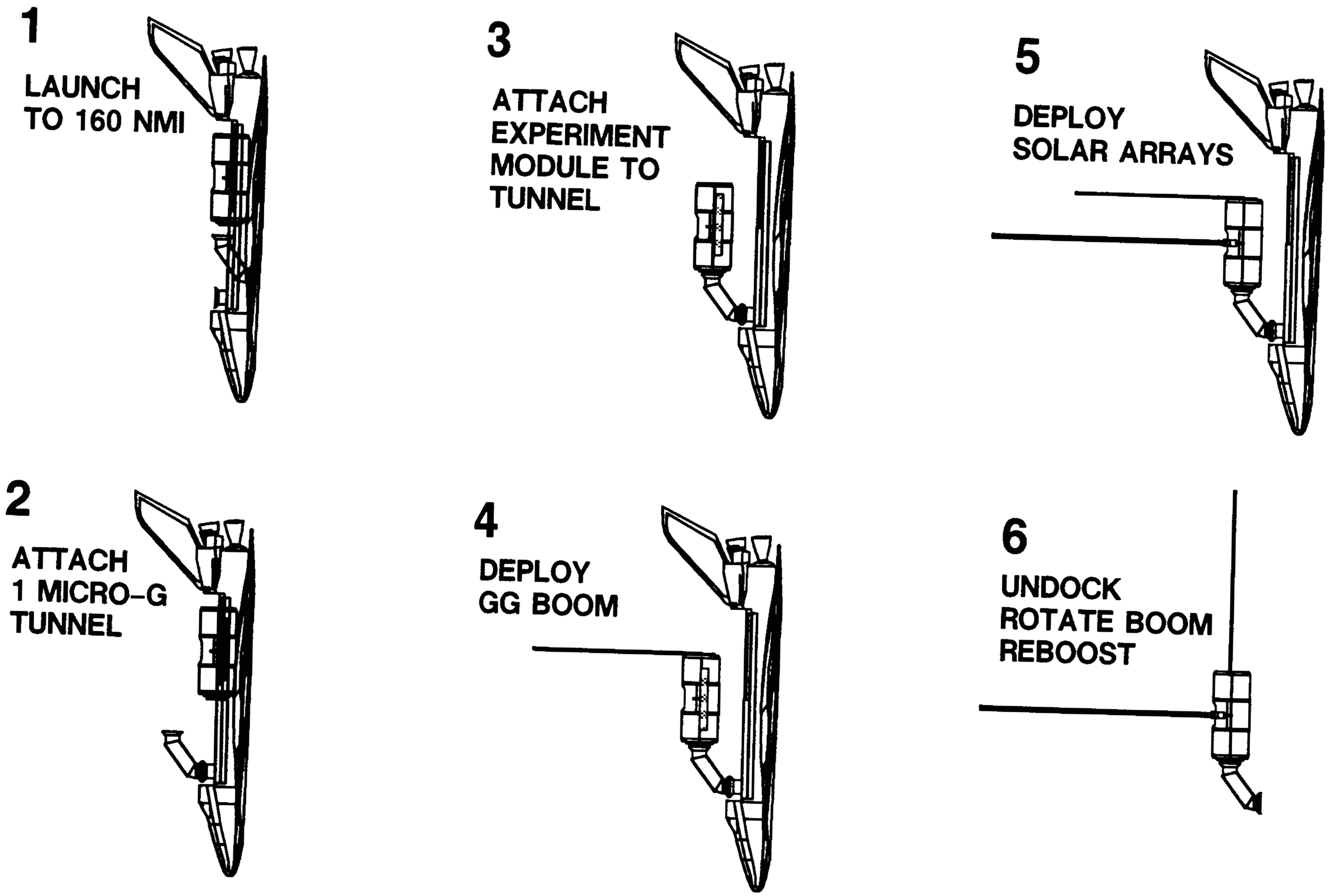
FIP20

8.1. DEPLOYMENT MISSION

DEPLOYMENT OF CDSF CONCEPT #1 WITH THE ONE MICRO-G TUNNEL

CDSF concept #1 is deployed at an altitude of 160 n.mi. The orbiter first orients itself in a nose down gravity gradient attitude. The RMS then removes the one micro-g tunnel and attaches it to the docking adapter at which time it is secured by IVA personnel. The CDSF is then removed from the cargo bay by the RMS and berthed to the one micro-g tunnel. At this point an IVA crew member secures the connection between the tunnel and the CDSF. The gravity gradient boom is then either attached by the RMS (assuming a solid boom stowed in the orbiter door sill) or deployed (deployable mast concept) so that it is perpendicular to the orbiter bay. The boom will later be rotated on its hinged base when the CDSF is clear of the orbiter. Next the solar arrays are commanded to be deployed enabling the CDSF to be powered up and operational. At the end of the mission, the interface between the one micro-g tunnel and the docking adapter is unsecured by IVA personnel enabling the RMS to unberth the CDSF from the orbiter. Once the orbiter is at a safe distance, the gravity gradient boom is commanded to rotate so that it is aligned with the longitudinal axis of the CDSF resulting in a stable configuration. The orbiter then returns to Earth and the CDSF reboosts to an altitude such that in 6 months the orbit will have decayed to the 174n.mi. rendezvous altitude.

DEPLOYMENT OF CDSF CONCEPT #1 WITH 1 MG TUNNEL

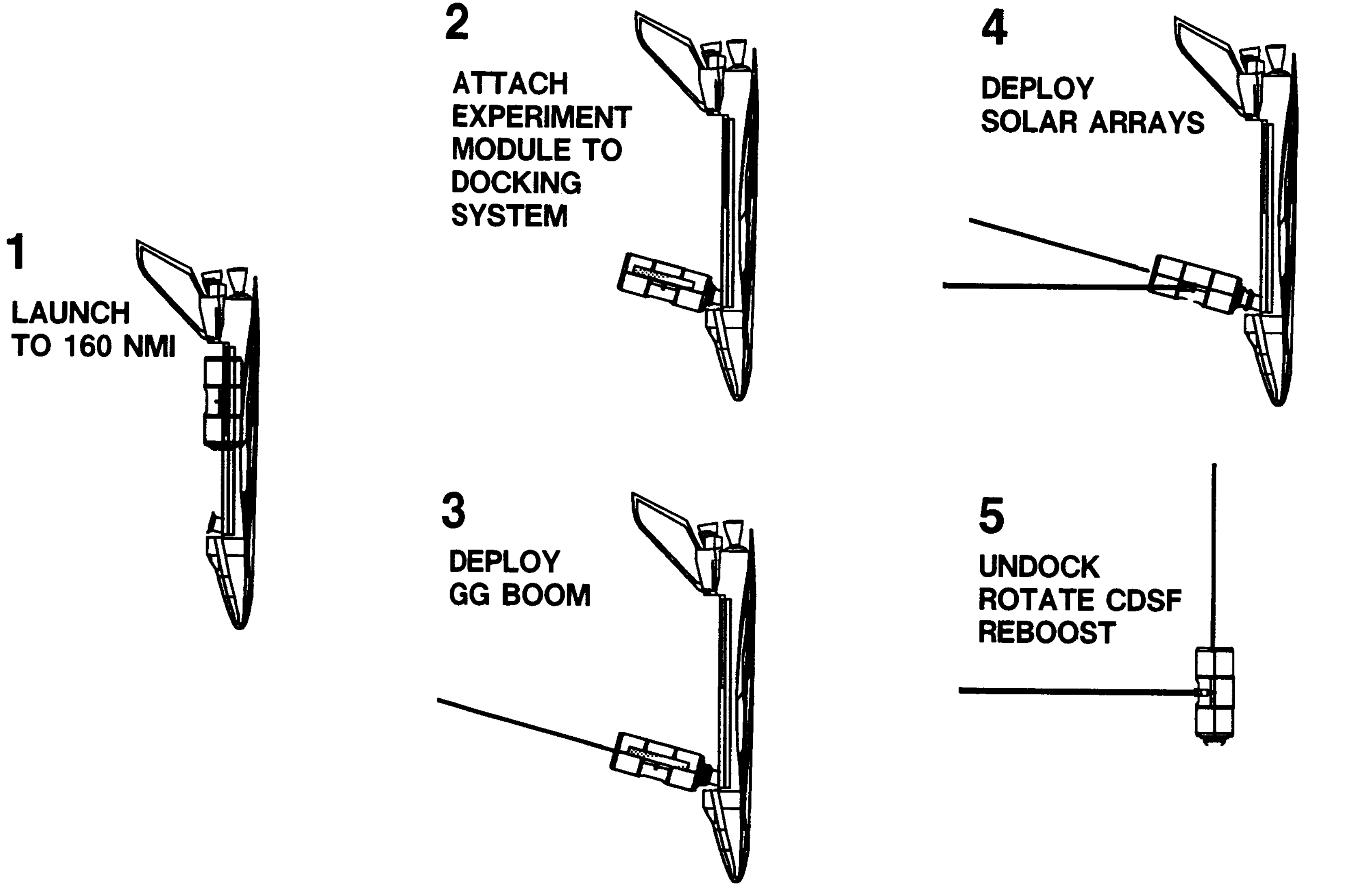


DEP100T

DEPLOYMENT OF CDSF CONCEPT #1 WITHOUT THE ONE MICRO-G TUNNEL

CDSF concept #1 is deployed at an altitude of 160 n.mi. The orbiter first orients itself in a nose down gravity gradient attitude. The experiment module is then removed from the cargo bay by the RMS and berthed to the docking adapter. At this point an IVA crew member secures the connection between the docking adapter and the experiment module and prepares the experiment module for crew habitability. The gravity gradient boom is then either attached by the RMS (assuming a solid boom stowed in the orbiter door sill) or deployed (deployable mast concept) so that it is perpendicular to the orbiter bay. Next the solar arrays are commanded to be deployed enabling the CDSF to be powered up and operational. At the end of the mission, the interface between the experiment module and the docking adapter is unsecured by IVA personnel enabling the RMS to unberth the CDSF from the orbiter. Once the orbiter is a safe distance from the CDSF, the experiment module is commanded to rotate so that its longitudinal axis is aligned along local vertical resulting in a stable configuration. The orbiter then returns to Earth and the CDSF reboosts to an altitude such that in 6 months the orbit will have decayed to the 174 n.mi. rendezvous altitude.

DEPLOYMENT OF CDSF CONCEPT #1 WITHOUT 1 MG TUNNEL



DEP100NT

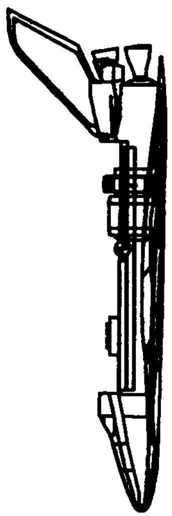
DEPLOYMENT OF CDSF CONCEPT #2

CDSF concept #2 is deployed at an altitude of 175 n.mi. The orbiter first orients itself in a nose down gravity gradient attitude. The experiment module is then removed from the cargo bay by the RMS and berthed to the docking adapter. At this point an IVA crew member secures the connection between the docking adapter and the experiment module and prepares the experiment module for crew habitability. The gravity gradient boom is then either attached by the RMS (assuming a solid boom stowed in the orbiter door sill) or deployed (deployable mast concept) so that it is perpendicular to the orbiter bay. Next the solar array is commanded to be deployed enabling the CDSF to be powered up and operational. At the end of the mission, the interface between the experiment module and the docking adapter is unsecured by IVA personnel enabling the RMS to unberth the CDSF from the orbiter. Once the orbiter is a safe distance from the CDSF, the experiment module is commanded to rotate so that its longitudinal axis is aligned along local vertical resulting in a stable configuration. The orbiter then returns to Earth and the CDSF reboosts to an altitude such that in 6 months the orbit will have decayed to the 202 n.mi. rendezvous altitude.

DEPLOYMENT OF CDSF CONCEPT #2

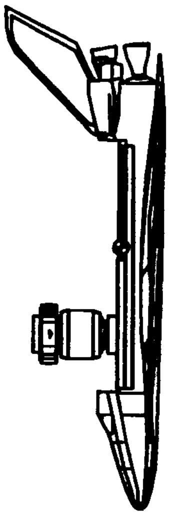
1

LAUNCH TO
175 NMI



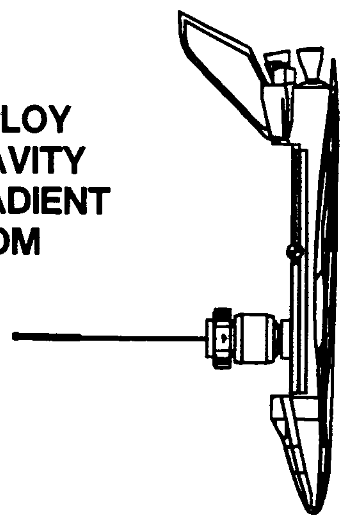
2

ATTACH
EXPERIMENT
MODULE TO
DOCKING
SYSTEM



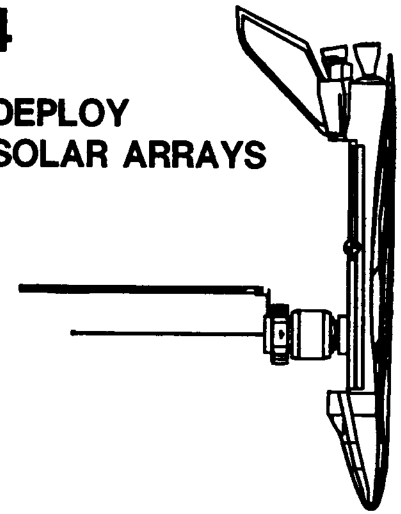
3

DEPLOY
GRAVITY
GRADIENT
BOOM



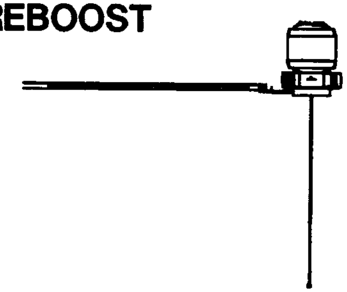
4

DEPLOY
SOLAR ARRAYS



5

UNDOCK
ROTATE CDSF
REBOOST



DEP20

NASA

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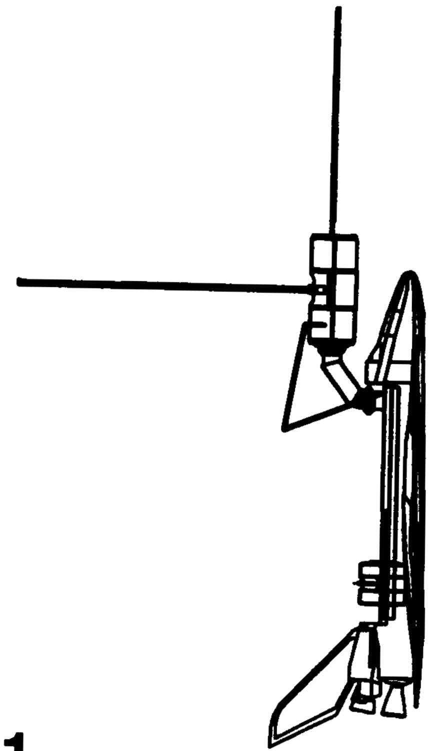
8.2. RESUPPLY MISSION

RESUPPLY OF CDSF CONCEPT #1 WITH ONE MICRO-G TUNNEL

Special operations must be performed when the one micro-G tunnel is attached to the CDSF. In the normal berthing mode, the CDSF is parallel and just above the orbiter cargo bay resulting in limited RMS access. Since the resupply module cannot be removed from the cargo bay in the normal berthing mode, the CDSF must be berthed to the orbiter using a 180 degree rotation that results in an accessible cargo bay with the CDSF oriented out over the nose of the orbiter. Once the orbiter captures and berths to the CDSF in this rotated configuration, the gravity gradient boom is rotated 90 degrees so that it is perpendicular to the cargo bay resulting in a stable configuration. At this point the RMS can remove the resupply module from the cargo bay and attach it to the CDSF. IVA crew members can then secure the resupply module and proceed with any rack change outs. The resupply module could then be removed by the RMS or left on orbit attached to the CDSF. For one micro-g operations, the orbiter would have to unberth from the CDSF, rotate 180 degrees and then re-berth to the CDSF in the normal berthing configuration. At the end of the mission, the interface between the one micro-g tunnel and the docking adapter is unsecured by IVA personnel enabling the RMS to unberth the CDSF from the orbiter. Once the orbiter is at a safe distance, the gravity gradient boom is commanded to rotate so that it is aligned with the longitudinal axis of the CDSF resulting in a gravity gradient stable free flyer. The orbiter then returns to Earth and the CDSF reboosts to an altitude such that in 6 months the orbit will have decayed to the 174 n.mi. rendezvous altitude.

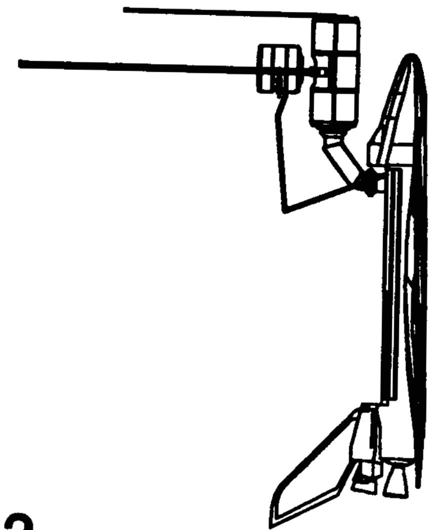
res#!wt

RESUPPLY OF CDSF CONCEPT #1 WITH 1 MICRO-G TUNNEL



1

RENDEZVOUS,
CAPTURE AND BERTH CDSF,
ROTATE GRAVITY GRADIENT
BOOM FOR STABILITY,
REMOVE SUPPLY MODULE
FROM CARGO BAY

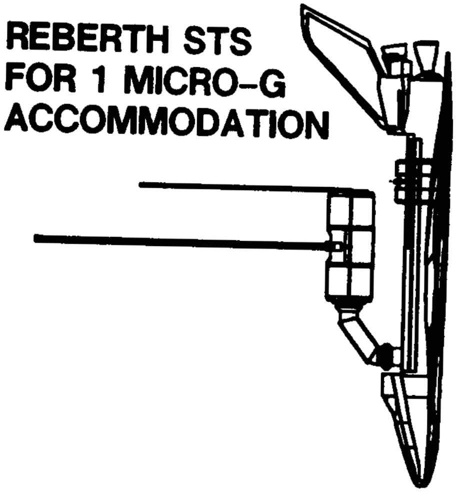


2

ATTACH SUPPLY MODULE,
CHANGE OUT RACKS,
RETURN SUPPLY MODULE TO
CARGO BAY (OPTIONAL)

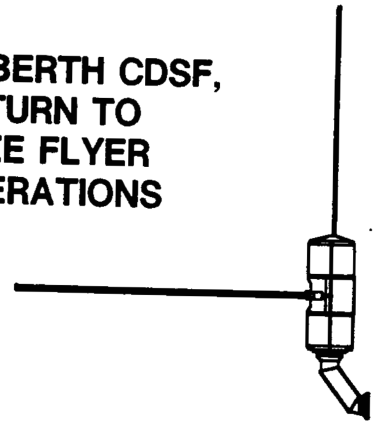
3

REBERTH STS
FOR 1 MICRO-G
ACCOMMODATION



4

UNBERTH CDSF,
RETURN TO
FREE FLYER
OPERATIONS

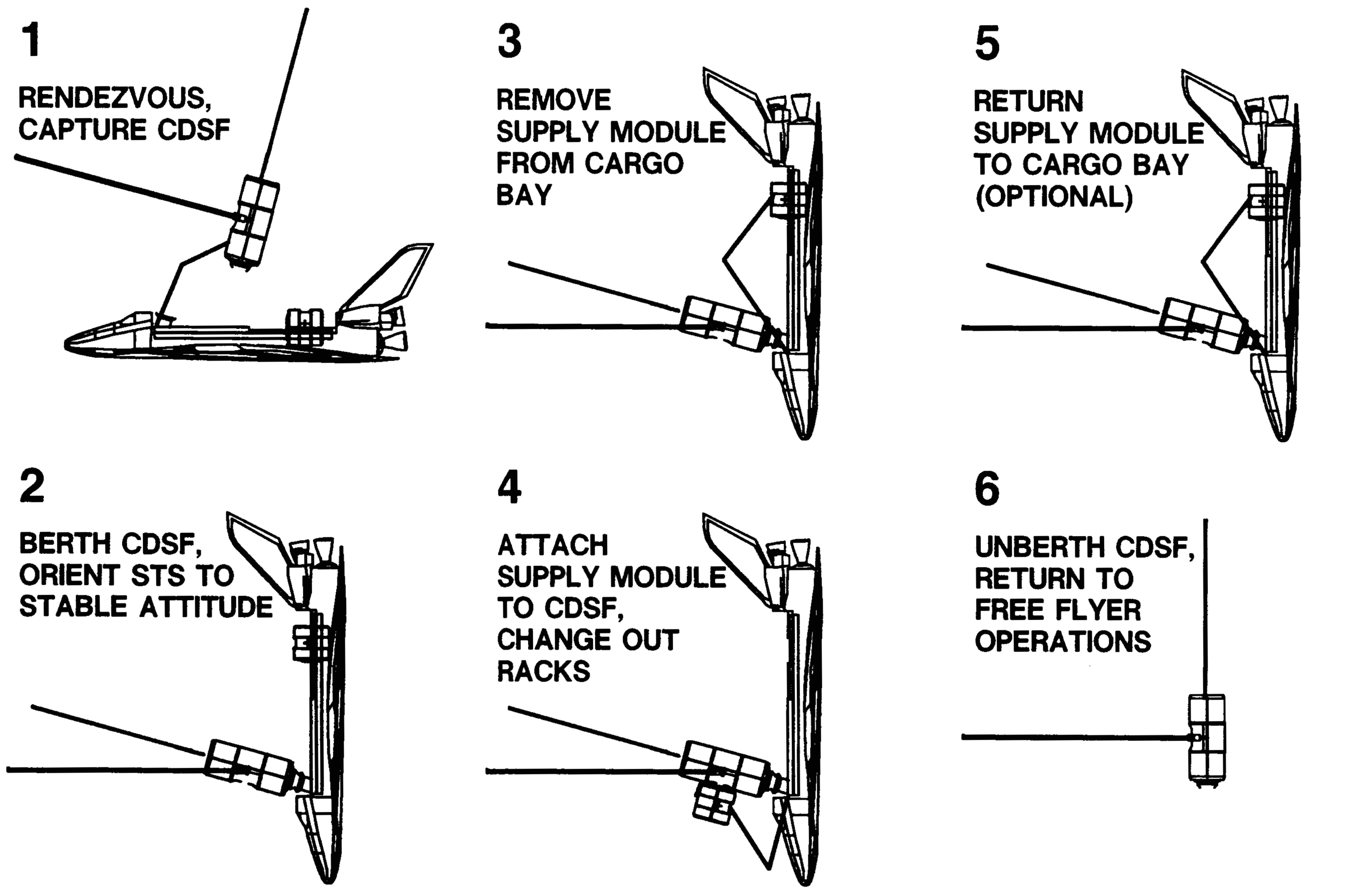


RESUP100T

RESUPPLY OF CDSF CONCEPT #1 WITHOUT THE ONE MICRO-G TUNNEL

Resupply of CDSF concept #1 without the one micro-g tunnel is less complicated. After rendezvous, the orbiter berths with the CDSF using the RMS at an altitude of 174 nautical miles. The orbiter then orients the mated configuration to the nose down stable attitude followed by the proper rotation of the CDSF solar arrays. At this point the RMS can remove the resupply module from the cargo bay and attach it to the CDSF. IVA crew members can then secure the resupply module and proceed with any rack change outs. The resupply module could then be removed by the RMS or left on orbit attached to the CDSF. At the end of the mission, the interface between the CDSF and the docking adapter is unsecured by IVA personnel enabling the RMS to unberth the CDSF from the orbiter. Once the orbiter is at a safe distance, the CDSF is commanded to rotate so that its longitudinal axis is aligned along local vertical resulting in a gravity gradient stable free flyer. The orbiter then returns to Earth and the CDSF reboosts to an altitude such that in 6 months the orbit will have decayed to the 174 n.mi. rendezvous altitude.

RESUPPLY OF CDSF CONCEPT #1 WITHOUT 1 MG TUNNEL

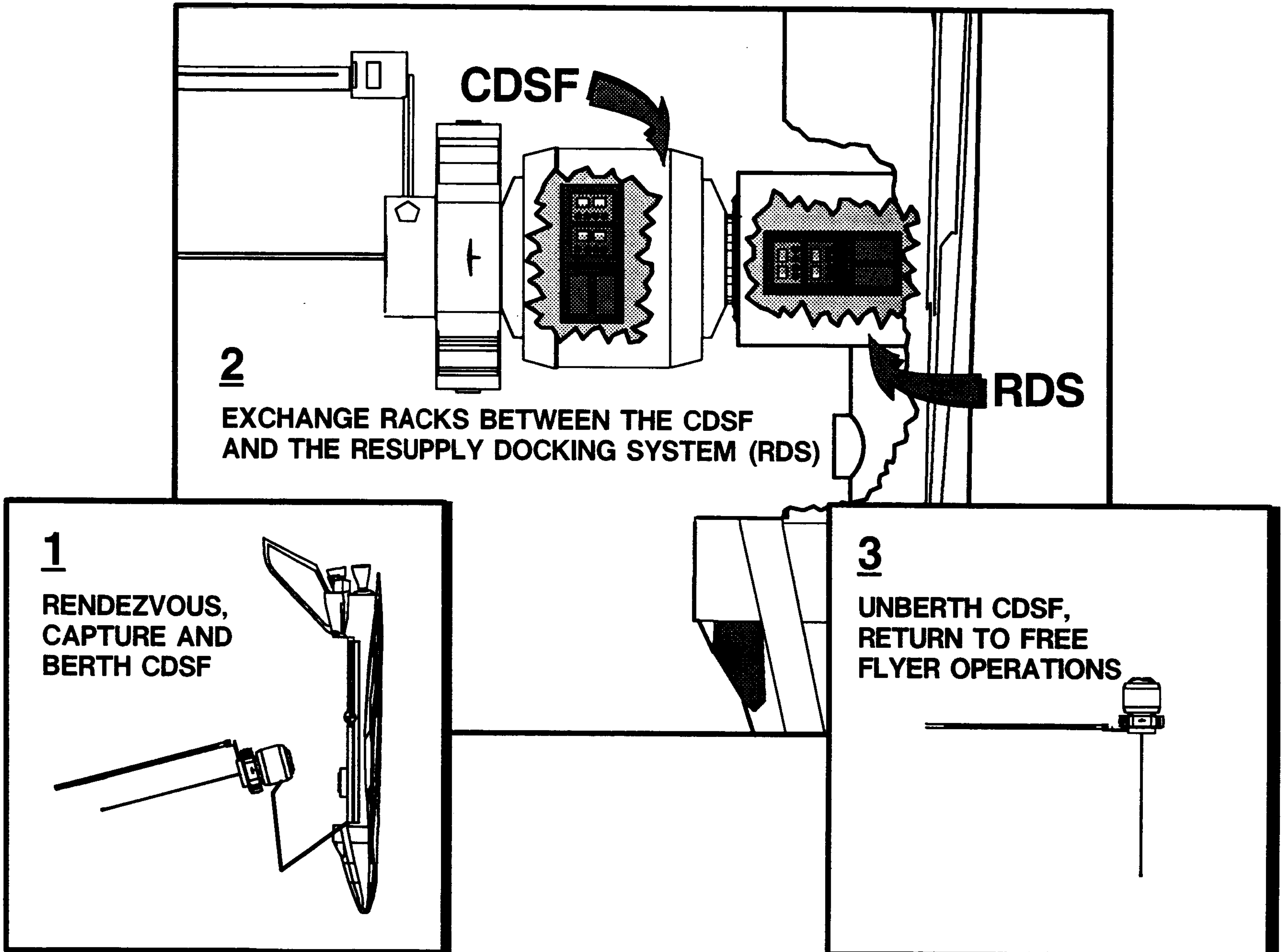


RES100NT

RESUPPLY OF CDSF CONCEPT #2

Resupply of CDSF concept #2 involves the use of the Resupply/Docking System (RDS). After rendezvous, the orbiter berths the CDSF to the RDS using the RMS at an altitude of 202 n.mi. The orbiter then orients the mated configuration to the nose down stable attitude followed by the proper rotation of the CDSF solar arrays. IVA crew members can then secure the CDSF to the RDS and proceed with any rack change outs. At the end of the mission, the interface between the experiment module and the RDS is unsecured by IVA personnel enabling the RMS to unberth the CDSF from the orbiter. Once the orbiter is a safe distance from the CDSF, the CDSF is commanded to rotate so that the longitudinal axis of the experiment module is aligned along local vertical resulting in a gravity gradient stable free flyer. The orbiter then returns to Earth and the CDSF reboosts to an altitude such that in 6 months the orbit will have decayed to the 202 n.mi. rendezvous altitude.

RESUPPLY OF CDSF CONCEPT #2



RES20

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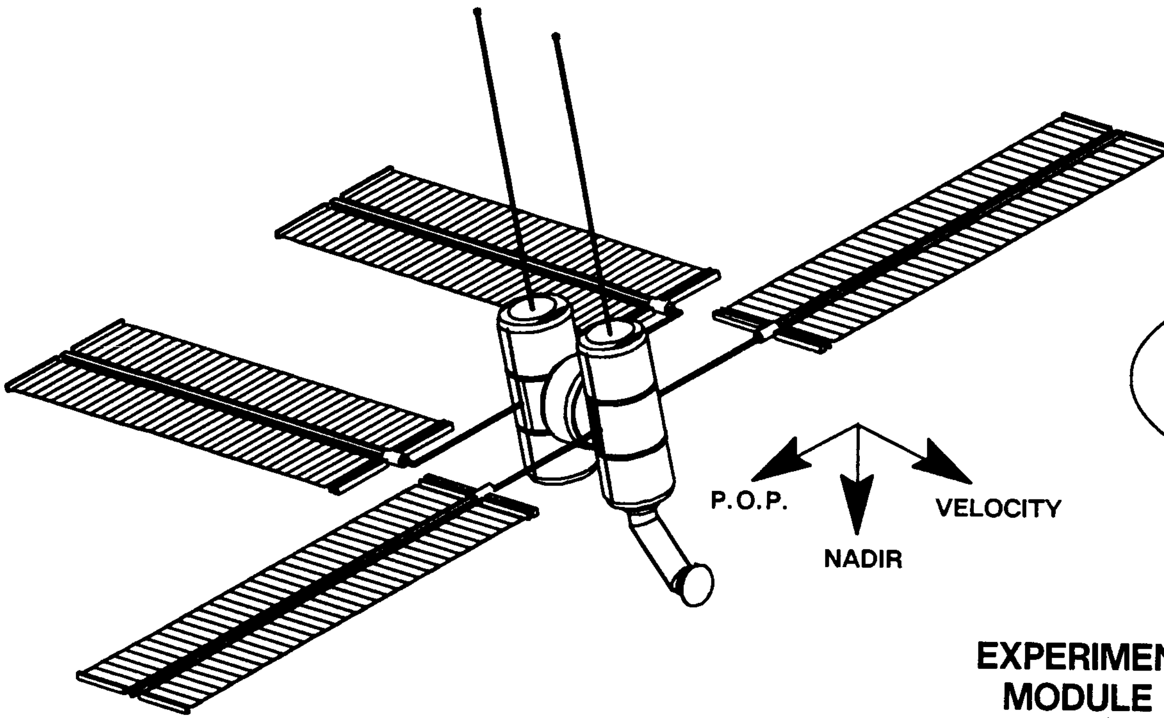
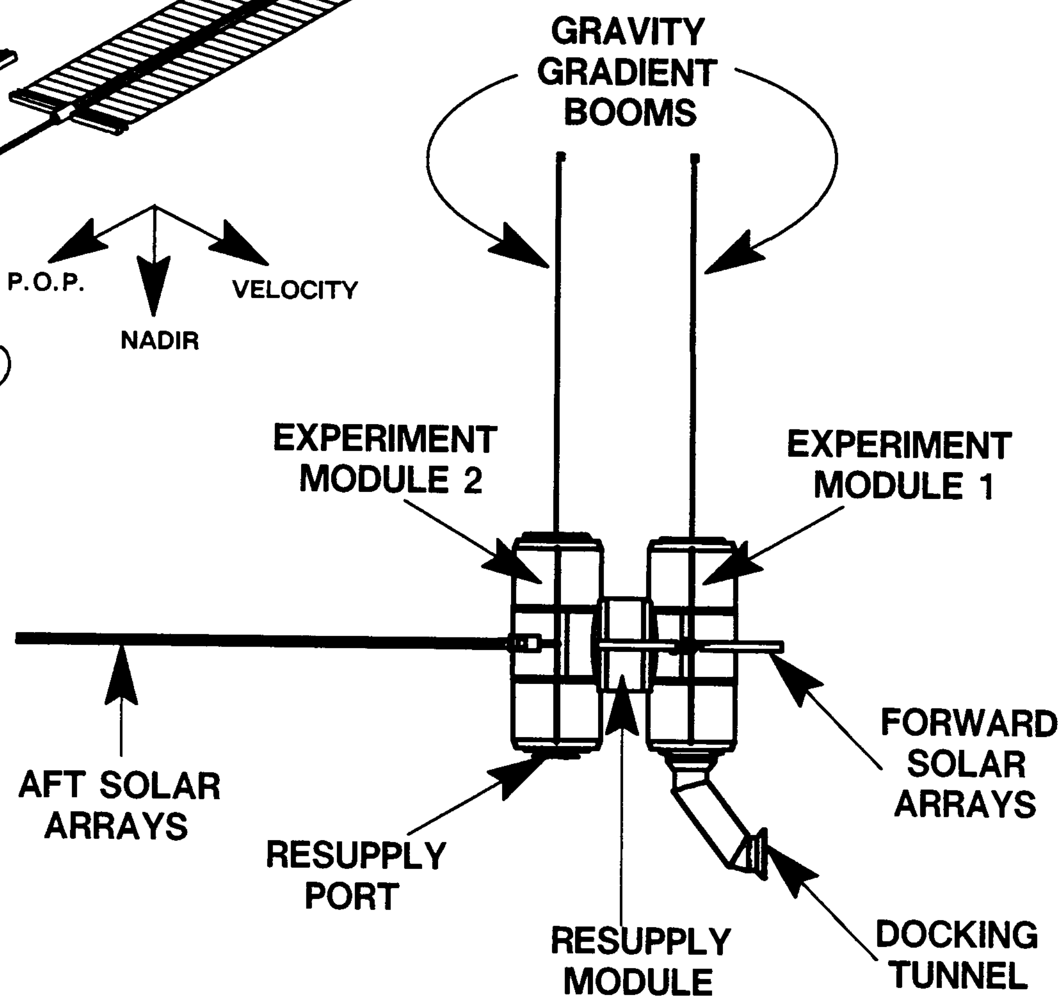
8.3. GROWTH CONSIDERATIONS

CDSF CONCEPT #1 GROWTH CONFIGURATION

CDSF concept #1 can grow to a dual module configuration by making use of a resupply module that has hatches at both ends. This resupply module is used as a connecting module between the two experiment modules resulting in a 100% increase in pressurized volume. The solar arrays on the original experiment module would be rotated 90 degrees to allow the arrays on the second module to be deployed in the "folded" configuration. Depending on the amount of outfitting in the second experiment module and the available orbiter used for launch, the growth phase could be completed in one or two STS missions.

CDSF CONCEPT #1 GROWTH CONFIGURATION



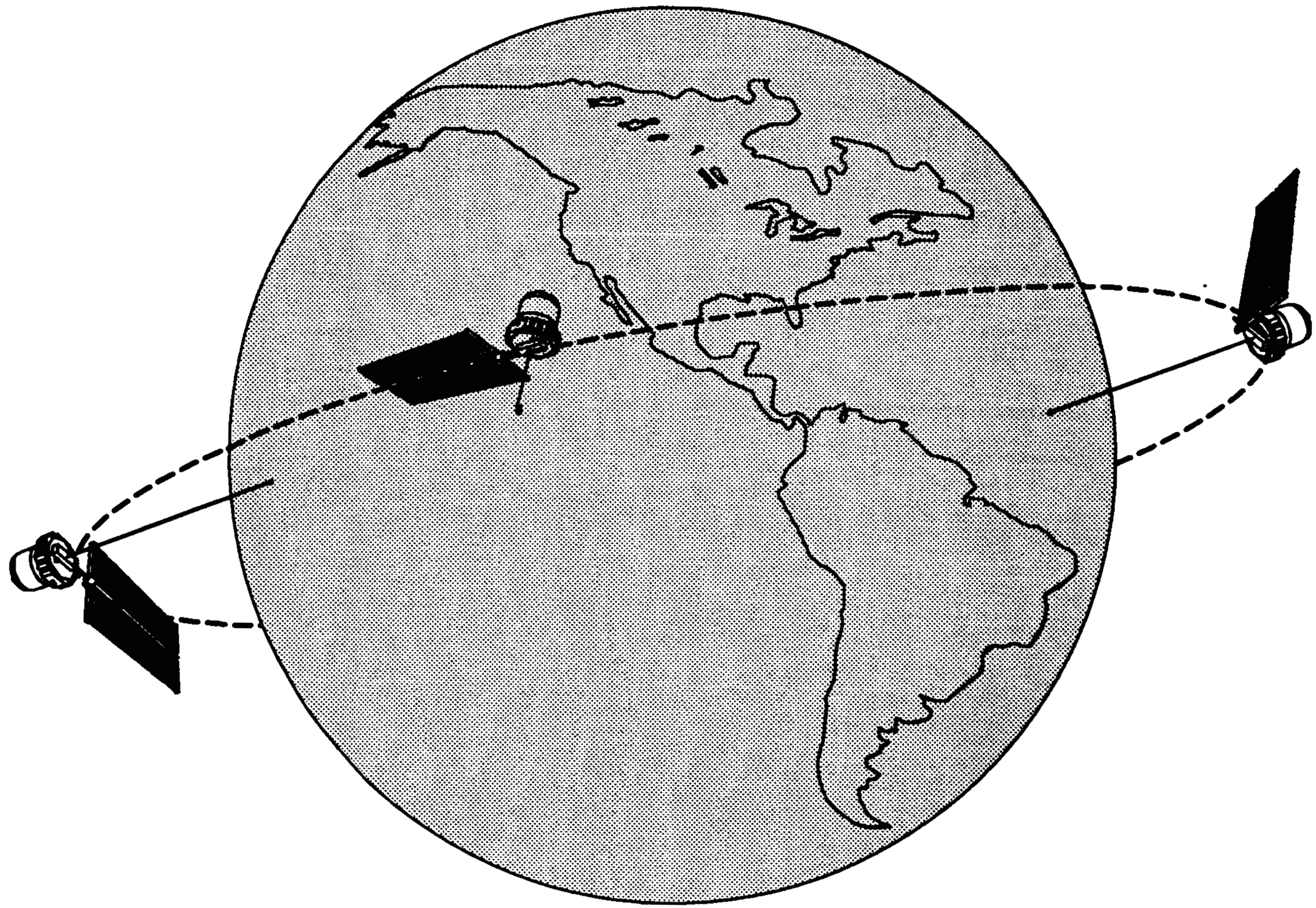


A RESUPPLY MODULE WITH HATCHES AT BOTH ENDS CAN BE USED TO ATTACH A SECOND EXPERIMENT MODULE RESUTING IN A 100% INCREASE IN CDSF CAPACITY

CDSF CONCEPT #2 GROWTH CONFIGURATION

CDSF concept #2 can grow by deploying multiple facilities in orbit. These multiple facilities could fly in formation in a single orbit or have individual orbits. The smaller size of concept #2 could result in "specialized" facilities such that each has a specific class of payloads and servicing requirements that could be accommodated by a single orbiter mission.

CDSF CONCEPT #2 GROWTH CONCEPT



CDSF CONCEPT #2 CAN GROW BY DEPLOYING MULTIPLE FACILITIES IN ORBIT

GROWTH20

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8.4. RETRIEVAL/DISPOSAL MISSION

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8.4 RETRIEVAL/ DISPOSAL

Following completion of the five year CDSF mission lifetime, the vehicle can either be retrieved by the Orbiter and returned to Earth intact, or allowed to decay into the Earth's lower atmosphere. The primary disadvantage of the former is the cost associated with the Shuttle retrieval mission. The disadvantage of the re–entry disposal scenario relates to the safety concerns associated with potential surface impacts. A preliminary study was performed to analyze the critical parameters to assure a controlled and graceful orbit degradation.

Based on the Skylab experience, and on concurrent studies of the Long Duration Exposure Facility (LDEF), it is estimated that up to 30% of the original CDSF mass may reach the surface of the Earth intact. Hence, a brief survey was performed to determine the error in predicting the size and location of the debris impact area for the purpose of assuring that populated regions would not be exposed.

Based on the LDEF study, the debris dispersion might be expected to span approximately plus or minus 150 to 200 Nm about the nominal (intact) impact point. Thus the question becomes : what size de–orbit thruster is required to assure that the nominal impact point can be achieved (in the presence of maneuver execution errors, atmospheric uncertainties, and loss of attitude control – tumbling)? The proposed Concept 1 CDSF has only the attitude control thrusters of 0.1 lb force. The Concept 2 CDSF utilizes a spacecraft bus similar to an OMV whereby up to four of the 12.5 lb thrusters can simultaneously fire for a total of 50 lb of de–orbit thrust.

For the preliminary analysis performed, an initial 28.5 degree inclined 150 Nm circular orbit was assumed. It was also assumed that CDSF attitude maintenance could not be guaranteed below 400,000 ft. Other assumptions are listed on the page opposite.

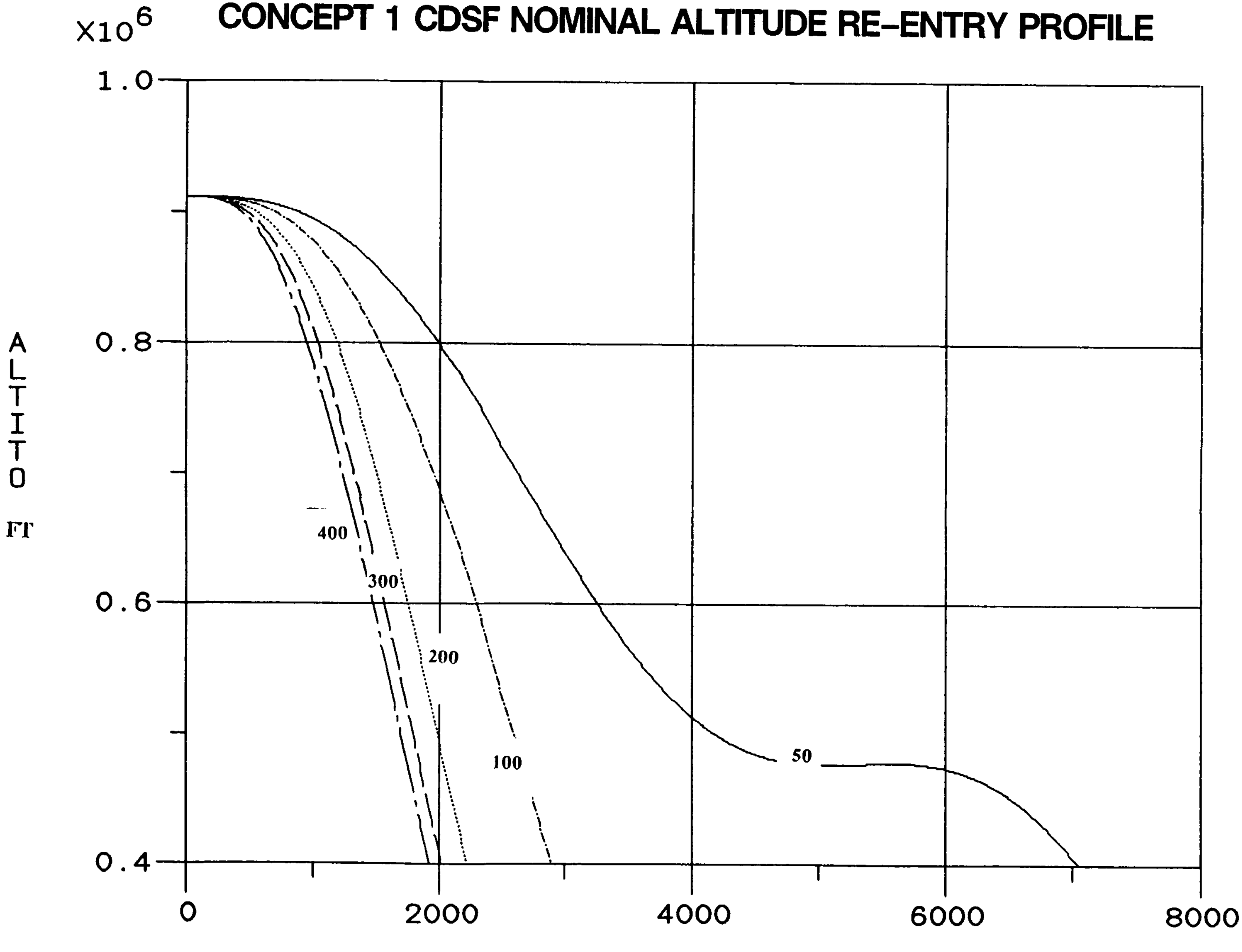
CDSF BALLISTIC COEFFICIENT CHARACTERISTICS

	CONCEPT 1	CONCEPT 2
MASS	15,131 KG (33,360 LB)	11,683 KG (25,756 LB)
DRAG COEFFICIENT	2.3	2.3
MIN AREA	40 MET**2	20 MET**2
MAX AREA	50 MET**2	22 MET**2

CDFS ALTITUDE DECAY VS TIME PROFILE

To accurately predict the nominal impact point required a sufficiently steep flight path angle following completion of the de-orbit burn. Starting at 150 Nm (911,500 ft), re-entry trajectory profiles were generated for analysis using five thruster sizes of 400, 300, 200, 100, and 50 lb thrusters. Of the five, only the 50 lb thruster required a continuous burn down to 400,000 ft altitude. The facing page shows the nominal altitude vs time profile starting at 150 Nm altitude for the Concept 1 CDSF. Note that the larger thrusts had a relatively quick re-entry compared to the 50 lb thruster.

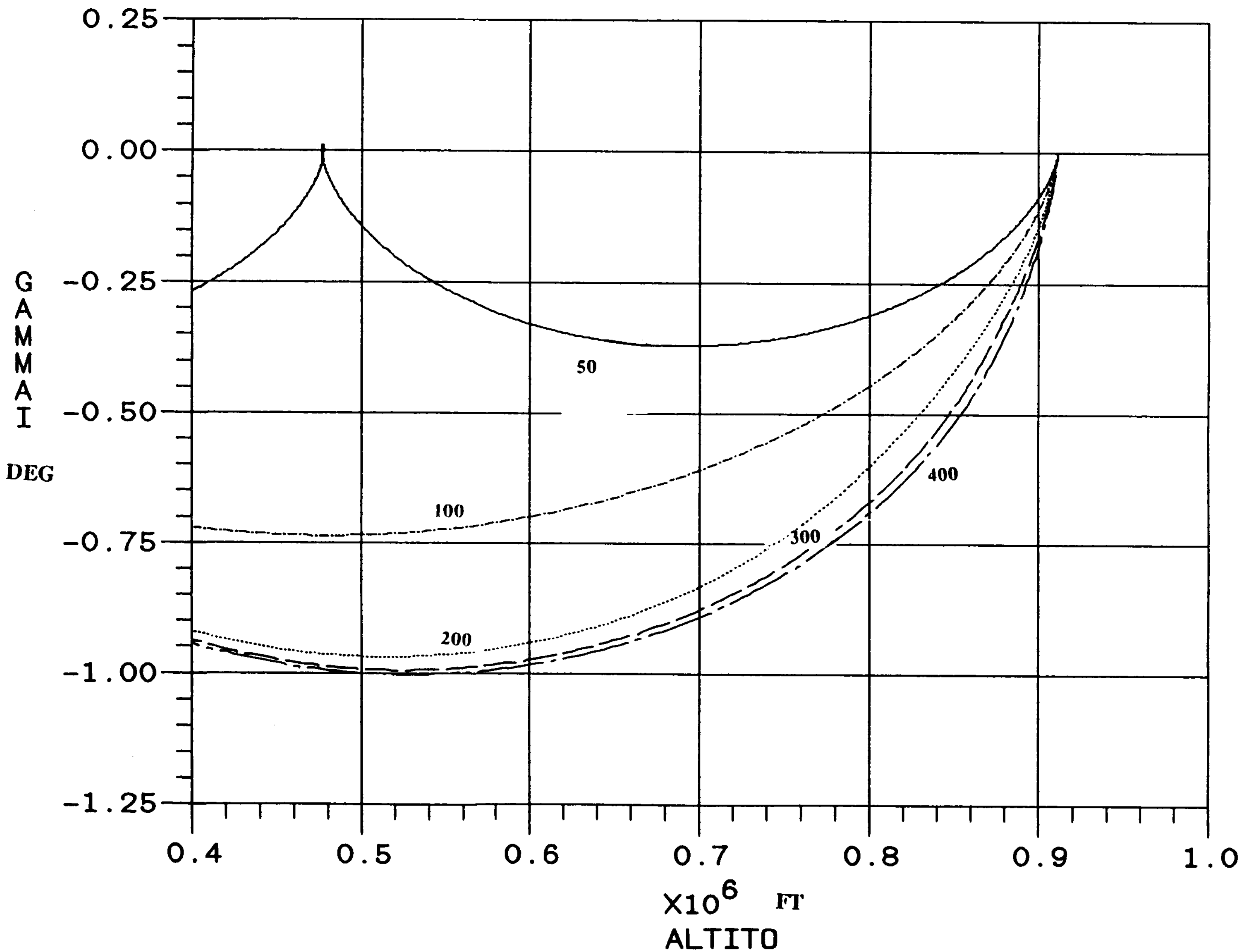
CONCEPT 1 CDSF NOMINAL ALTITUDE RE-ENTRY PROFILE



CDFS FLIGHT PATH ANGLE TIME HISTORY

The flight path angle gamma (degrees) vs altitude (ft) during the five descent cases is shown. Note that the 50 lb thruster profile returns to a zero flight path angle during the descent, which explains the longer descent timeline shown on the previous page. Use of a deorbit thrust level as small as 50 lbs would require multiple revolution de-orbit operation scenarios. Needless to say, absolutely no confidence could be placed in predicting the nominal impact point for a 0.1 lb de-orbit thrust.

CONCEPT 1 CDSF FLIGHT PATH ANGLE RE-ENTRY PROFILE



CDSF DOWNRANGE IMPACT DISPERSIONS

A parametric study of 3 error sources was performed to determine the dispersion of the impact point.

De-orbit ignition timing errors yield a downtrack position error on the order of 4 Nm. for every 1 second error.

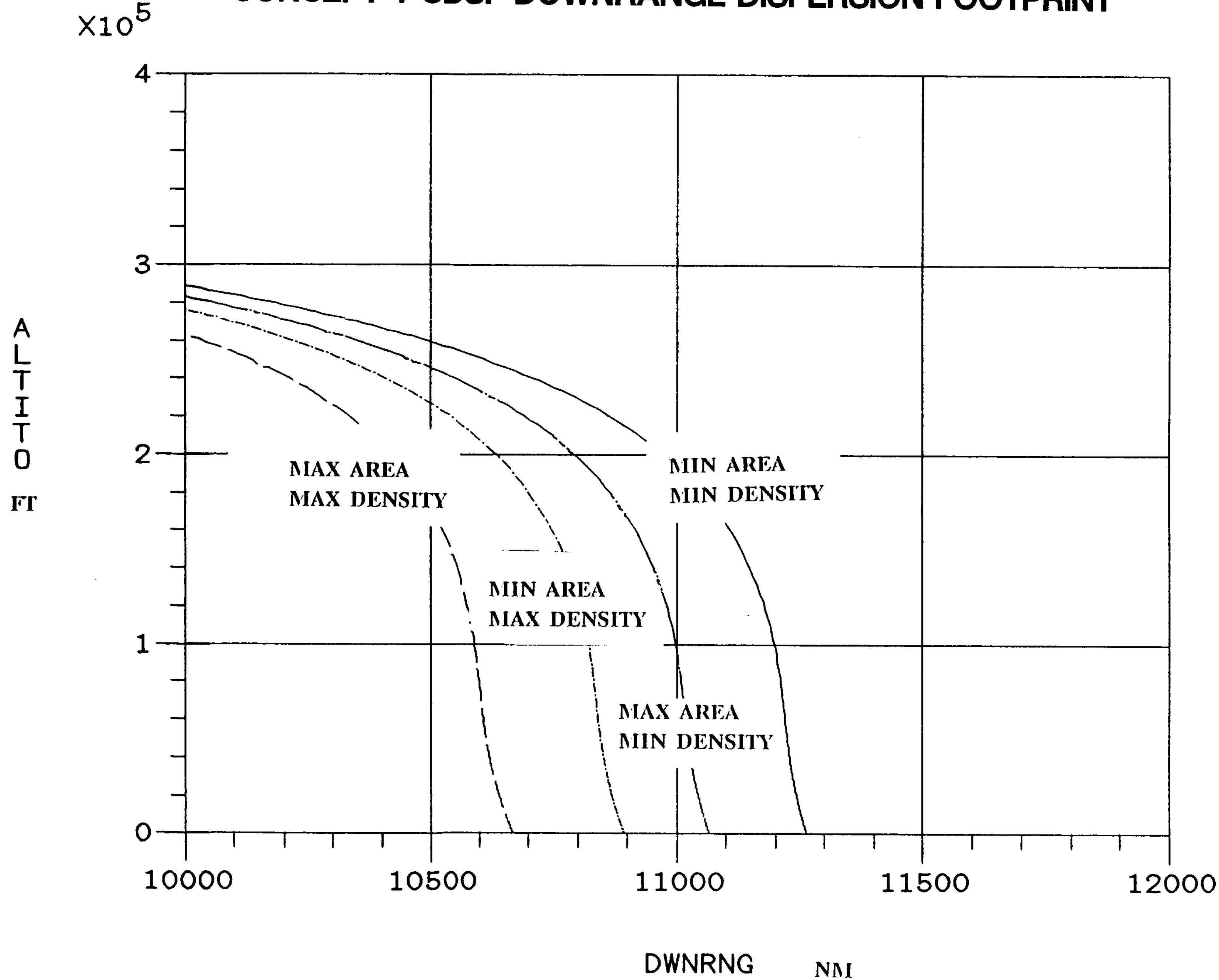
Day of landing atmospheric uncertainties were simulated by adjusting the density by plus or minus 20% during the entire re-entry trajectory. A worst case projected area vs a totally controlled attitude re-entry was also simulated (note, however, that the min/max area ratios for Concepts 1 and 2 are only 0.8, and 0.9 respectively). The results of these assumptions are shown for the 50 lb thruster case. Note that the distance from the shortest re-entry (max area, max density) and the longest re-entry (min area, min density) yield a possible spread of up to plus or minus 250 Nm for the Concept 1 CDSF configuration. The Concept 2 configuration yields a slightly smaller dispersion due to the smaller min/max area ratio.

Since the break-up dispersion is relatively independent of the atmospheric/area dispersion in the prediction of the impact footprint, the two can be combined using a root sum squared (RSS) method to give approximately a plus or minus 325 Nm uncertainty in predicting where parts of the CDSF may impact the Earth.

In conclusion, the CDSF orbit decay rate disposal option could be targeted to within about a 650 Nm spread with a 50 lb de-boost thruster, although it would take in excess of one orbit to impact (assuming attitude control down to 400,000 ft). Although the Concept 2 CDSF configuration nominally has a 50 lb thrust capability, a conservative approach would be to augment the thrusters for both concepts to achieve 100 lb total de-boost thrust capability. Further analysis would be required to determine at what altitude the CDSF would lose attitude control.

Thus, either an upfront cost associated with provision of thrust capacity required for deboost, or, an end of mission cost associated with thruster augmentation, must be borne to accommodate the disposal scenario. On balance, it would appear that the most cost effective *and* safe approach would be to retrieve the CDSF intact with a shared (non-dedicated) Orbiter mission which can accommodate the retrieval in the cargo bay.

CONCEPT 1 CDSF DOWNRANGE DISPERSION FOOTPRINT



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9.0 MISSION CONTROL AND DATA HANDLING (MCDH)

PURPOSE

THE PURPOSE OF THIS SECTION IS TO PROVIDE A CDSF OPERATIONS SCENARIO IN THE MAN-TENDED (OR STS) MODE AND THE FF MODE IN ORDER TO DEVELOP A CONCEPTUAL DESIGN FOR THE CDSF MDHS AND COMMUNICATIONS SYSTEMS.

PURPOSE

- CDSF CONCEPTIONAL-LEVEL ANALYSIS & CONCEPT FOR:

  1. FLIGHT OPERATIONS SCENARIO
     a. MAN-TENDED MODE
     b. FREE-FLYER (FF) MODE

  2. MISSION DATA HANDLING SYSTEM (MDHS)
     a. ON-BOARD MDHS
     b. GROUND MDHS

  3. COMMUNICATIONS NETWORK COMPONENTS
     a. SPACE NETWORK
     b. GROUND NETWORK

- STUDY UTILIZED :

  1. SCIENTIFIC EXPERIMENT DATA

  2. NASA CDSF DOCUMENTATION

  3. OTHER NASA DOCUMENTATION

STUDY LIMITATIONS

THIS STUDY IS LIMITED TO AVAILABLE SCIENTIFIC EXPERIMENT DATA THAT IS ORIENTED TO MAN-TENDED NASA MISSIONS AND PLANNED SPACE STATION APPLICATIONS. THE VALIDITY OF THESE DATA VOLUMES, FREQUENCIES AND DURATIONS FOR THE CDSF DURING THE FREE FLYER (FF) MODE PRESENTED IN THIS SECTION IS ASSUMED. FOR EXAMPLE, IT IS NOT KNOWN WHETHER EXPERIMENT OWNERS WOULD BE WILLING TO USE OR PAY FOR MORE EXTENSIVE USE OF TELESCIENCE TECHNIQUES WHICH REQUIRE HIGH RATE VIDEO AND A HIGH DEGREE OF ON BOARD AUTOMATION FOR SPACECRAFT/EXPERIMENT OPERATIONS. NO STRONG EVIDENCE OF THIS NEED WAS EVIDENT IN THE DESCRIPTION OF THE DERIVED CDSF CANDIDATE EXPERIMENT LIST. FOR ON BOARD CDSF EXPERMENT OPERATIONS AND STANDARD SPACECRAFT SUBSYSTEM HOUSEKEEPING OPERATIONS, PAST PROVEN ON BOARD PROGRAMMED OPERATIONS ARE DEFINED TO IMPLEMENT FREE FLYER MISSION OPERATIONS SEQUENCES UTILIZING UNMANNED SPACECRAFT OPERATIONAL METHODOLOGY AND TECHNIQUES. STANDARD SHUTTLE ORBITER COMPATIBLE REAL TIME AND PLAYBACK VIDEO RATES ARE ASSUMED FOR BOTH STS/CDSF AND FF MISSIONS.

THE UTILIZATION OF REALTIME INTERACTIVE TELESCIENCE IS A CAPABILITY THAT SHOULD BE CONSIDERED FOR FREE FLYER CDSF MISSIONS IN THE LATER SPACE STATION FREEDOM PERIOD OF THE LATE 1990'S. AUTOMATED EXPERIMENT OPERATIONS, ONBOARD AND GROUND CONTROL TELEOPERATIONS AND LOW SPACE/TERRESTRAL COMMUNICATION NETWORK THROUGHPUT DELAY METHODS AND TECHNIQUES NEED TO BE DEVELOPED AND MADE OPERATIONAL. THIS IS A KEY DEVELOPMENT FOR THE FREEDOM STATION OPERATIONS THAT WILL PAVE THE WAY FOR TELESCIENCE UTILIZATION BY EXPERIMENT USERS OF SPACE FACILITIES. IT IS NOT SEEN AS A NEED FOR IMPLEMENTATION IN THE PROPOSED EARLY TO MID 1990'S CDSF PRE-FREEDOM 5 YEAR LEASE PERIOD.

STUDY LIMITATIONS

- STUDY CONDUCTED AT CONCEPTUAL LEVEL ONLY

- AVAILABLE EXPERIMENT DATA ORIENTED TO MAN-TENDED MODE & THEREFORE :
  1. ASSUMED DATA RATES POTENTIALLY HIGHER FOR FREE FLYER EXPERIMENTS
  2. VALIDITY OF FREE FLYER EXPERIMENTS UNKNOWN
  3. STUDY BASIS LIMITED TO EXPERIMENT DATA VALIDITY

- SELECTED DESIGN OPTIONS ARE DRIVEN BY MISSION EXPERIMENT COMPLEMENT CHARACTERISTICS

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9.1 CDSF EXPERIMENT DATA MISSION MODELS

EXPERIMENT ASSUMPTIONS

THE SELECTED EXPERIMENT COMPLEMENT REPRESENTS A TYPICAL RANGE OF DATA REQUIREMENTS DURING A CDSF MISSION. THESE EXPERIMENTS WERE SELECTED FROM THE REFERENCED TELEDYNE-BROWN ENGINEERING RACO REPORT IN SECTION 4.2 AND THE CANDIDATE CDSF EXPERIMENT LIST DERIVED IN SECTION 4.2.1. EXPERIMENTS WITH HIGHER VIDEO DATA RATE REQUIREMENTS ARE ANTICIPATED. EXPERIMENT COMPLEMENTS WERE MODELED FOR EITHER AN STS MISSION OR A FREE FLYER MISSION. TWO (2) COMPLEMENT MODELS WERE ANALYZED: 1) A SEVEN (7) DAY STS MISSION WITH TWELVE (12) EXPERIMENTS (FOUR (4) WITH VIDEO), AND 2) A CDSF FREE FLYER MISSION WITH ELEVEN (11) EXPERIMENTS (FOUR (4) WITH VIDEO). THE SEVEN (7) DAY STS MISSION WAS SUBJECTED TO A DETAILED ANALYSIS AND IT HAD WORST CASE DATA MANAGEMENT LOADING. THE EXAMPLE STS MISSION WAS LIMITED TO A ONE (1) DAY TIMELINE AND DATA RATE ANALYSIS.

EXPERIMENT ASSUMPTIONS

- SELECTED EXPERIMENT COMPLEMENT
  - REPRESENTS MODELS WITH TYPICAL RANGE OF DATA REQUIREMENTS DURING CDSF MISSION
  - EXPERIMENTS SELECTED FROM TELEDYNE BROWN ENGINEERING RACO REPORT & CANDIDATE CDSF EXPERIMENT LIST
  - ANTICIPATE EXPERIMENTS WITH HIGHER VIDEO DATA RATES
  - MODELS ASSUME 70 % CDSF
  - SEPARATE EXPERIMENT COMPLEMENTS MODELED FOR STS MISSION & FREE FLYER MISSION
  - MODELS DO NOT ADDRESS MIXED FREE FLYER & MAN-TENDED EXPERIMENT COMPLEMENTS
  - EXPERIMENT COMPLEMENT MODELS ANALYZED :
    - 7 DAY STS = 12 EXPERIMENTS, 4 WITH VIDEO
    - CDSF FREE FLYER = 11 EXPERIMENTS; 4 WITH VIDEO
  - CDSF 7 DAY STS SUBJECTED TO DETAILED ANALYSIS
  - CDSF 7 DAY STS MISSION HAD WORST CASE DATA MANAGEMENT LOADING
  - EXAMPLE PAYLOAD MODEL ANALYSIS LIMITED TO A ONE-DAY TIMELINE AND DATA RATE ANALYSIS

CDSF/STS EXPERIMENT MISSION MODEL DATA HANDLING OPERATIONS

FURTHER ASSUMPTIONS ARE SUMMARIZED IN THE FOLLOWING CHARTS. NORMAL OPERATIONS CAN BE EITHER REAL TIME DATA DELIVERY, OR COMMAND UPLINK. DATA DELIVERY PRIORITIES ARE ASSIGNED TO CUSTOMER DATA. THE EXAMPLE MISSION TIMELINE SCHEDULE CONSIDERS ONLY DATA AND VIDEO SCHEDULING REQUIREMENTS.

CDSF/STS EXPERIMENT MISSION MODEL DATA HANDLING OPERATIONS

- NORMAL OPERATIONS CAN BE:
    1. REAL TIME DATA DELIVERY TO CDSF CUSTOMERS
    2. PLAYBACK DATA DELIVERY TO CDSF CUSTOMERS
    3. COMMANDS FOR SUBSEQUENT UPLINKS

- NORMAL OPERATIONS PRIORITIES TO CUSTOMERS:
    1. REAL TIME DATA
    2. PRIORITIZED PLAYBACK DATA
    3. UNPRIORITIZED PLAYBACK DATA

- EXAMPLE MISSION OPERATIONS DAY SCHEDULE DOES NOT CONSIDER CDSF SPACECRAFT POWER, THERMAL OR OTHER SUBSYSTEM DATA REQUIREMENTS - ONLY EXPERIMENT DATA

- EXPERIMENT RUN TIMES CAN BE CONTINUOUS OR SEGMENTED

SEVEN DAY STS EXPERIMENT MODEL

A SUMMARY OF THE SEVEN (7) DAY CDSF/STS EXPERIMENT MISSION MODEL IS SHOWN. THE TWELVE (12) EXPERIMENTS ARE LISTED WITH THEIR CORRESPONDING VOLUME, WEIGHT, AVERAGE AND PEAK POWER. THE NUMBER OF HOURS OF VIDEO DATA, THE DIGITAL DATA RATE, AND TOTAL EXPERIMENT RUN TIME.

SEVEN DAY CDSF/STS MISSION EXPERIMENT MODEL

EXPERIMENT	VOL(FT3)	WT(LBS)	AV.PWR (WATTS)	PK.PWR (WATTS)	VIDEO TIME (HRS)	DATA RATE (Kbps)	RUN TIME (HRS.)
1. POLYMER MICROSTRUCTURE & MORPHOLOGY	4.33	200	20	25	33.3	.5	100
2. PHYSICAL VAPOR TRANSPORT OF ORGANIC SOLIDS	6.53	376	125	190	72	2.5	96
3. FLUID EXPERIMENT SYSTEM	40.5	1085	100	1484	20	20.0	72
4. CHEMICAL VAPOR TRANSPORT	40.5	440	300	350		1.0	72
5. ACOUSTIC LEVITATION FAC.	10.5	440	1500	3000		32.0	2
6. SURFACE TENSION DRIVEN CONVECTION EXPERIMENT	4.0	111	50	180		.1	48
7. SOLID SURFACE COMBUSTION EXPERIMENT	8.0	130	80	160		.1	1
8. PHASE PARTITIONING EXPMT	2.0	12				.5	2
9. DROP PHYSICS MODULE	40.5	993	1000	2100		1.0	26
10. CRITICAL FLUID LIGHT SCATTERING EXPERIMENT	20.0	100	750	750		2.0	8
11. DROPLET COMBUSTION EXPMT	6.0	152	50	70		.1	1
12. FLUIDS EXPMT APPARATUS	2.0	80	50	200	36	.1	72
TOTAL STS	184.86	4119	4925	8509	161.3	58.1	500

FREE FLYER EXPERIMENT MODEL

A SUMMARY OF THE FREE-FLYER EXPERIMENT MISSION MODEL IS PRESENTED. THE NAMES OF THE EXPERIMENTS ARE LISTED EACH WITH ITS CORRESPONDING VOLUME, WEIGHT, AVERAGE AND PEAK POWER, VIDEO TIME, DIGITAL DATA RATE, AND EXPERIMENT RUN TIME.

FREE FLYER EXPERIMENT MODEL

EXPERIMENT	VOL (FT3)	WT (LBS)	AV.PWR (WATTS)	PK.PWR (WATTS)	VIDEO TIME (HRS)	DATA RAT (Kbps)	RUN T.IME (HRS.)
1. FLOAT ZONE CRYSTAL GROWTH FACILITY	4.30	295	2500	5000	25	1.5	1200
2. DIFFUSIVE MIXING OF ORGANIC SOLUTIONS	6.20	188	100	130	2	2.5	1200
3. PROTEIN CRYSTAL GROWTH	40.50	550	220	230		.1	672
4. ZEOLITE CRYSTAL GROWTH	18.00	400	600	1700		2.0	1008
5. ELECTRODEPOSITION	7.06	132.3	20	140		1.0	960
6. NON-LINEAR OPTICAL THIN FILMS	9.71	209.4	140	140		1.0	720
7. NON-LINEAR OPTICAL ORGANIC SOLUTIONS	7.00	119	100	130		1.0	720
8. DIRECTIONAL SOLIDIFICATION FURNACE	82.00	1200	3500	7000	25	3.0	672
9. ORGANIC SEPARATIONS	8.00	132	20	20		1.0	960
10. NON-LINEAR OPTICAL MONOMERS	9.70	210	140	140		1.0	720
11. LAMBDA POINT EXPERIMENT	40.50	880	450	500	7.5	5.0	1680
TOTAL FF	232.97	4315.7	7790	15130	82.5	19.1	10512

CDSF/STS EXPERIMENT MISSION MODEL VIDEO REQUIREMENTS

A SUMMARY OF THE VIDEO REQUIREMENTS FOR THE STS MISSION PROFILE IS PRESENTED. THE EXPERIMENTS WOULD REQUIRE SOME VIDEO DATA IN REAL TIME, SOME WITHIN SEVERAL ORBITS, AND SOME WITHIN HOURS OR DAYS; THE CDSF WILL PROVIDE A TRANSMISSION SCHEME SO THAT DELAYED DOWNLINK CAN BE PROVIDED WITH NO DATA LOSS. THE MINIMUM AVAILABLE CAPACITY WOULD BE 45 Mbps AND 4.25 MHz CAMERA SOURCES.

CDSF/STS EXPERIMENT MISSION MODEL VIDEO REQUIREMENTS

- STS MISSION EXAMPLE DAILY SCHEDULE ASSUMES EXPERIMENT #4 SCHEDULED ON DIFFERENT DAY DUE TO VIDEO REQUIREMENTS

- EXPERIMENTS REQUIRE SOME VIDEO:
    1. IN REAL TIME
    2. WITHIN AN ORBIT OR TWO
    3. WITHIN HOURS OR DAYS

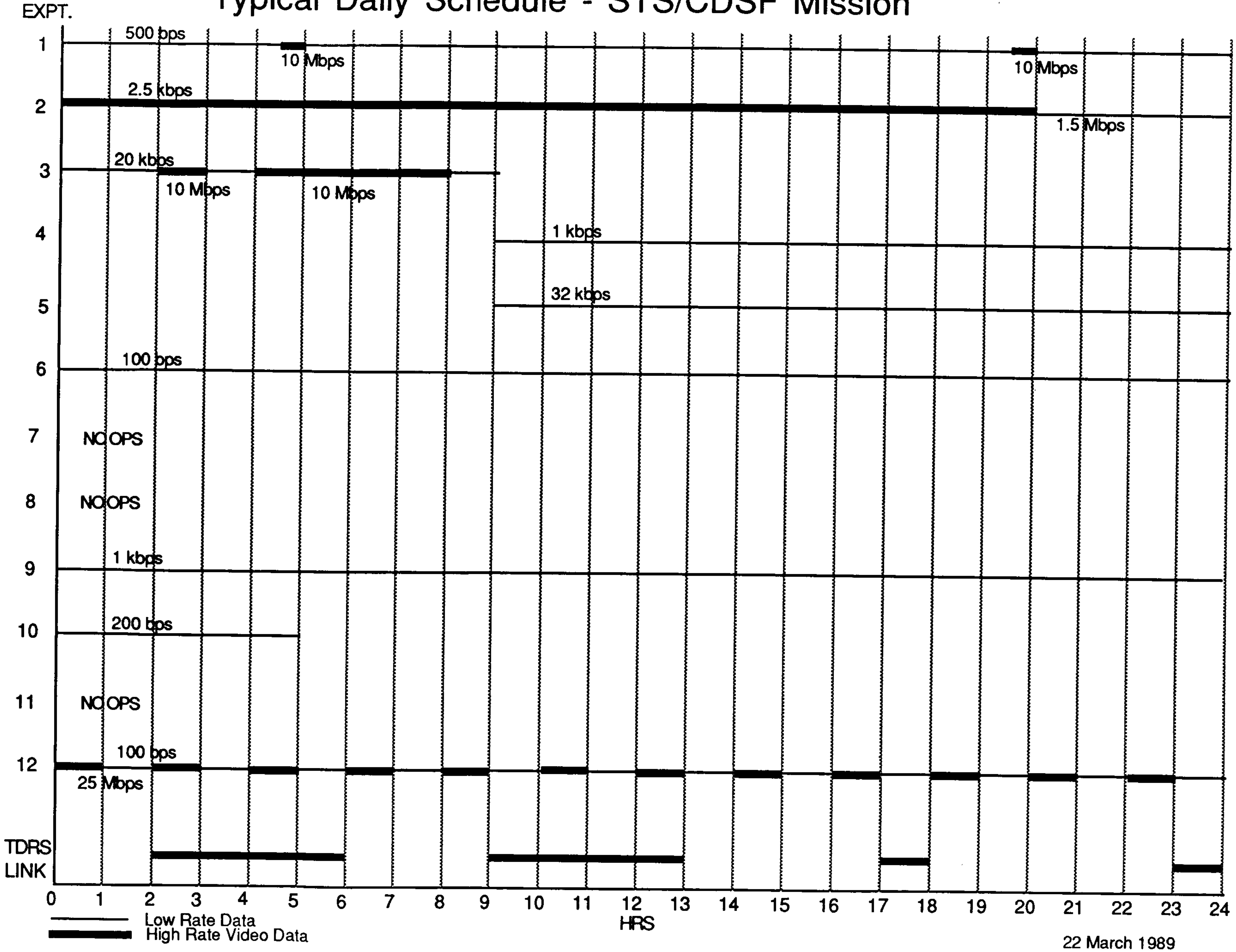
- CDSF WILL PROVIDE RECORDER CAPACITY AND /OR VIDEO COMPRESSION TO PERMIT DELAYED DOWNLINK WITH NO DATA LOSS

- ASSUMED MINIMUM AVAILABLE TDRSS CAPACITY TO CDSF (FF OR STS)
    1. 45 Mbps
    2. 4.25 MHz (CCTV OR EXPERIMENT) CAMERA SOURCES

CDSF/STS EXPERIMENT MISSION MODEL DAILY DATA SCHEDULE

THIS SCHEDULE REPRESENTS A TYPICAL DAILY TIMELINE FOR THE STS/CDSF MISSION. THE DATA AND VIDEO REQUIREMENTS OF THE 12 EXPERIMENTS ARE SCHEDULED FOR A PERIOD OF 24 HOURS. THE DOWNLINK TIME IS ALSO SHOWN.

Typical Daily Schedule - STS/CDSF Mission



22 March 1989

CDSF/STS MISSION MODEL EXPERIMENT DATA CHARACTERISTICS

THE EXPERIMENT DATA TYPES AND THEIR ASSOCIATED TRANSMISSION RATES AND RUN TIMES ARE SHOWN.

CDSF/STS MISSION MODEL EXPERIMENT DATA CHARACTERISTICS

- EXPERIMENT TELEMETRY & COMMAND DATA
  - EXPERIMENT SUBSYSTEM ENGINEERING DATA
  - EXPERIMENT SUBSYSTEM COMMAND DATA
  - SCIENTIFIC DATA
  - VIDEO DATA
    1. DIGITAL
    2. ANALOG

- EXPERIMENT DATA RATES & DURATIONS

DATA TYPE	MAX/MIN RATE	TOTAL DURATION PER DAY FROM ALL EXPERIMENTS EXP. RUN TIME
SCIENTIFIC	32 Kbps/ .1 Kbps	12.0 HR/DAY
VIDEO-STS	25 Mbps/ 0	5.0 HR/DAY
VIDEO-STS	10 Mbps/ 0	.26 HR/DAY
VIDEO-STS	COMPRS 1.5 Mbps	.25 HR/DAY
VIDEO-FF	25Mbps/ 0	.5 HR/DAY
VIDEO-FF	10Mbps/ 0	1.0 HR/DAY
VIDEO-FF	COMPRS 1.5 Mbps	

* SEE TYPICAL DAILY SCHEDULE FOR CDSF/STS MISSION

CDSF/STS EXPERIMENT MISSION MODEL DATA LOAD

A BREAKDOWN OF THE STS MISSION EXPERIMENT DATA BY EXPERIMENT DATA SOURCE SHOWS A TOTAL DATA VOLUME OF 1.41 TERABITS (Tb) PER DAY.

CDSF/STS EXPERIMENT MISSION MODEL DATA LOAD

TOTAL EXPERIMENT DATA VOLUME PER DAY:

EXPERIMENT 1=	43243 Mb
EXPERIMENT 2=	97416 Mb
EXPERIMENT 3=	180648 Mb
EXPERIMENT 4=	54 Mb
EXPERIMENT 5=	1728 Mb
EXPERIMENT 6=	8640 Mb
EXPERIMENT 7=	NO OPERATIONS
EXPERIMENT 8=	NO OPERATIONS
EXPERIMENT 9=	86 Mb
EXPERIMENT 10=	4 Mb
EXPERIMENT 11=	NO OPERATIONS
EXPERIMENT 12=	1080009 Mb

TOTAL EXPERIMENT DATA/DAY = 1.41 Tb PER DAY

CDSF/STS EXPERIMENT MISSION MODEL TDRSS LINK TIME

AN INDICATION OF THE START TIMES AND DURATIONS OF FOUR (4) 45 Mbps TDRSS LINKS ON A PER DAY BASIS IS SHOWN. THE NUMBERS DO NOT TAKE INTO ACCOUNT POSSIBLE SCHEDULE CONSTRAINTS. THE PROFILE ALSO ASSUMES THAT TELESCIENCE IS SCHEDULED DURING TDRSS LINKS AND THAT PLAYBACK DATA AND REAL TIME DATA IS TRANSMITTED DURING DOWNLINK TIMES. THE ESTIMATE FOR THE LINK DURATION WAS OBTAINED USING THE EXPERIMENTS (IN Mb), AND ASSUMING A MAXIMUM AVAILABLE CAPACITY OF 45 Mbps.

CDSF/STS EXPERIMENT MISSION MODEL TDRSS LINK TIME

4 TDRSS LINKS/DAY @ 45 Mbps:

- LINK 1 @ 0300 FOR 4 HRS
- LINK 2 @ 1000 FOR 4 HRS
- LINK 3 @ 1700 FOR 2 HRS
- LINK 4 @ 2200 FOR 3 HRS

NO SCHEDULE CONSTRAINTS (E.G., THERMAL, CREW) CONSIDERED OUTSIDE EXPERIMENT DATA

TELESCIENCE SCHEDULED DURING TDRSS LINKS

PLAYBACK DOWNLINKS PARALLEL WITH REAL TIME DATA DOWNLINKS

INITIAL LINK DURATION ESTIMATE= {DATA (MB)/45 MBPS * 36 60 } AND ROUNDING UP TO NEXT INTEGRAL HOUR

ACTUAL LINK BANDWIDTH= DATA (MB)/60

SUMMARY OF CDSF/STS EXPERIMENT MISSION MODEL DATA RATES

THE DATA RATES WERE DERIVED FROM THE CDSF CANDIDATE EXPERIMENT LISTS OF SECTION 4.2.1 OF THIS REPORT. ITEM 4 SHOWS THE CDSF EXPERIMENT VIDEO RATES FALL WITHIN VARIOUS COMMERCIAL VIDEO APPLICATION RATES.

THE RANGE DATA VOLUMES AND DURATIONS USE BOTH DATA TYPES, STORED AND REAL TIME VIDEO AND DATA AND ARE REPRESENTED IN THE EXPERIMENT MODEL ANALYSIS.

SUMMARY OF CDSF/STS EXPERIMENT MISSION MODEL DATA RATES

- EXPERIMENT DATA RATE ASSUMPTIONS

1. CDSF CANDIDATE EXPERIMENTS NEED DATA RATES FROM 100 bps - 32 Kbps
2. CDSF CANDIDATE EXPERIMENTS NEED VIDEO RATES FROM 1Mbps - 67 Mbps/HIGHER
3. RACO SURVEY STATES 25% EXPERIMENTS VIDEO REQUIREMENTS = 4.25 MHz (67Mbps)
4. OTHER VIDEO DATA RATES & BANDWIDTH APPLICATIONS ARE :

VIDEO SOURCE	DATA RATE/BANDWIDTH REQMT
BROADCAST TV	100Mbps
TELECONFERENCE	1.5 Mbps
CATV CHANNELS	6MHz
MEDIA QUALITY/PAO	22 Mbps
SPACE STATION VIDEO CHS	1.5 - 22Mbps
DOCKING VIDEO	22 Mbps
STS CCTV & PAYLD VIDEO	4.25 MHz ANALOG

5. DATA GENERATED CONTINUOUSLY DURING EXPERIMENT RUN TIME
6. EXPERIMENT DATA VIDEO STORED ON BOARD FOR DELAYED TRANSMIT TO OPTIMIZE LINK USE
7. REAL TIME TELESCIENCE VIDEO AND COMMAND TO BE OFFERED AS SCHEDULED OPTION

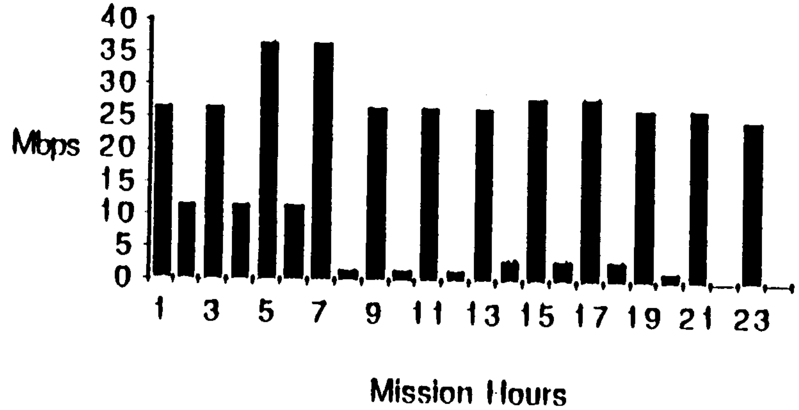
- EXPERIMENT DATA VOLUMES FOR CDSF STS EXAMPLE PAYLOAD ANALYSIS ARE SHOWN ON THE FOLLOWING PAGE.

CDSF/STS MISSION DATA MODEL DAILY VOLUME AND RATES

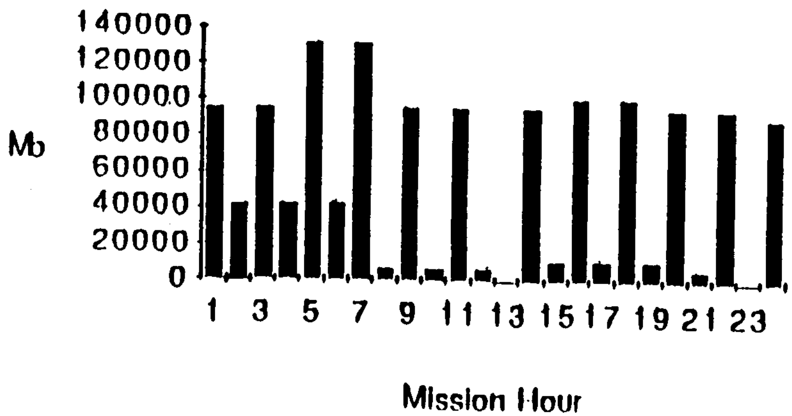
A HISTOGRAM OF THE DAILY DATA VOLUME AND DATA RATES PER MISSION HOUR IS SHOWN FOR THE DERIVED CDSF/STS EXPERIMENT MISSION DATA MODEL.

CDSF/STS MISSION DATA MODEL DAILY VOLUME AND RATES

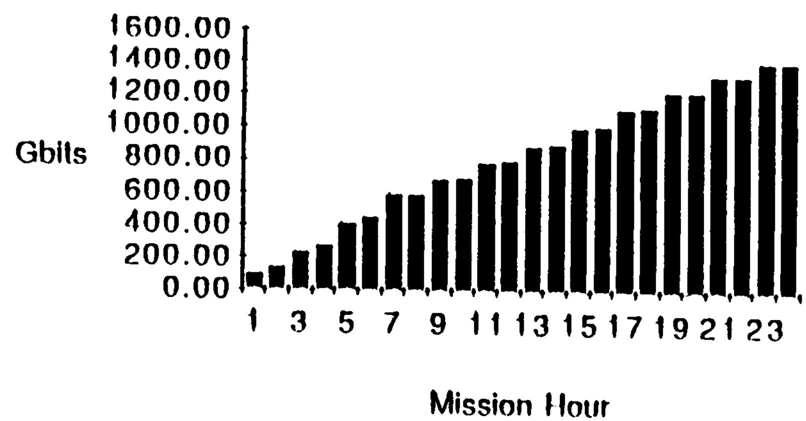
Hourly Data Rates for Example Timeline



Hourly Data Volume of Example Timeline



Data Accumulation for Example Timeline



CONCLUSIONS

A SUMMARY OF THE RESULTS OF THE EXPERIMENT COMPLEMENT MODEL ARE PRESENTED. BASIC CONCLUSIONS INVOLVING THE VARIETY OF DATA RATES AND THE AMBIGUITY OF THE VIDEO REQUIREMENTS DEMAND THAT THE CDSF DESIGN BE FLEXIBLE TO HIGHER RATES. THE DESIGN WILL IMPOSE RESTRICTIONS ON THE EXPERIMENT COMPLEMENT AND COULD REQUIRE SIMULATION CAPABILITIES FOR EXTENSIVE SCHEDULING OF THE EXPERIMENT OPERATIONS.

CONCLUSIONS

- EXPERIMENT SUBSYSTEM ENGINEERING (NON-VIDEO) & COMMAND DATA ARE LOW RATE
- EXPERIMENT SCIENTIFIC DATA ARE LOW TO MODERATE RATE
- EXPERIMENT ENG & SCIENTIFIC DATA WILL HAVE AVERAGE RATE TREND VS TIME
- EXPERIMENT ANALOG & DIGITAL VIDEO ARE HIGH RATE & SHOULD BE EXPECTED TO INCREASE
- EXPERIMENT VIDEO HAS BURST RATE TREND VS TIME
- EXPERIMENT VIDEO REQUIREMENTS COULD BE FUTURE DRIVING CDSF COMMUNICATION REQUIREMENTS
- EXPERIMENTS REQUIRING HIGH RATE VIDEO WOULD BE LESS CONSTRAINED IN FF MODE --STS IMPOSES THROUGHPUT CONSTRAINTS
- CDSF EXPERIMENT COMPOSITE DATA RATE = .9 Kbps - BURSTS OF 50 Mbps & UP
- TDRSS NETWORK USE WILL IMPOSE SCHEDULE-DRIVEN EXPERIMENT OPS MODE

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9.2 FLIGHT OPERATION DATA HANDLING SCENARIO

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FLIGHT OPERATIONS ASSUMPTIONS

THIS SECTION DESCRIBES THE FLIGHT OPERATIONS SCENARIOS FOR THE CDSF MISSION BOTH IN THE FREE FLYER AND STS MODES. THE SCENARIOS INCLUDE ALL PHASES OF THE MISSION FROM LAUNCH TO FLIGHT OPERATION TO SPACE AND GROUND DATA HANDLING. THE SCENARIOS FORM THE BASIS FOR THE SPACE AND GROUND DATA HANDLING SYSTEMS CONCEPT IN SECTION 9.3.

THIS SECTION ALSO LISTS THE ASSUMPTIONS MADE REGARDING INTERFACES WITH NASA. THE REQUIRED CUSTOMER SERVICES (NOT ALL CUSTOMERS ARE THE SAME), AND CDSF LEASE CONTRACTOR RESPONSIBILITIES FOR CDSF MISSION OPERATIONS. THE CDSF CONTRACTOR PROVIDES LEASE SERVICES TO FUNCTION AS THE DIRECT INTERFACE TO NASA FOR STS MISSION OPERATIONS, TDRS USE AND FLIGHT DYNAMICS SUPPORT. THESE SERVICES PROVIDE THE DIRECT INTERFACE TO CUSTOMERS FOR ALL THEIR MISSION SUPPORT. REQUIRED SUPPORT TO EXPERIMENTS IS EXPECTED TO REMAIN SIMILAR TO NASA MISSIONS.

FLYING AN STS MISSION AND USING TDRS, THE SPACE LINK OF CHOICE, GIVES THE CDSF GROUND SYSTEM SEVERAL INTERFACES WITH NASA AS WELL AS TO PUBLIC COMMUNICATIONS SERVICES FOR GROUND DATA TRANSPORT. BUT ALL CDSF DATA PROCESSING IS DONE BY CDSF CONTRACTOR FACILITIES. FLIGHT CONTROL OF THE CDSF IS ALSO DONE FROM A DEDICATED CDSF CONTRACTOR FACILITY USING CDSF CONTRACTOR PERSONNEL.

CDSF MISSIONS ALLOW FLIGHT OPERATIONS CUSTOMER INTERACTION WHILE ALSO PROVIDING SUPPORT TO MORE PASSIVE AND THIRD PARTY USERS.

FLIGHT OPERATIONS ASSUMPTIONS

- ALL MISSION OPERATIONS AND DATA PROCESSING PERFORMED BY CDSF CONTRACTOR (CC)
- MISSION OPERATIONS SCENARIO INDEPENDENT OF FACILITY LOCATIONS
- FLIGHT OPERATIONS INTERACTION WITH EXPERIMENT BY CUSTOMER IS SUPPORTED
- CC MISSION OPERATIONS HAVE SOME DEGREE OF AUTOMATION TO REDUCE MANPOWER COSTS WITH MINIMAL RISK TO MISSION READINESS
- CC SCHEDULING RESPONSIBILITY:
    - MISSION TIMELINE
    - NCC/TDRSS
    - GROUND COMMUNICATIONS
    - STS OPERATIONS
    - public communications services
- CC RESPONSIBLE FOR ALL NASA AND PUBLIC COMMUNICATIONS NETWORK TECHNICAL INTERFACES
- CC WILL CONTRACT WITH NASA GSFC FLIGHT DYNAMICS FACILITY FOR:
    - TDRSS ANTENNA EPHEMERIDES
    - FLIGHT DYNAMICS DATA
    - ORBITAL ANALYSIS DATA
    - EPHEMERIS DATA

FLIGHT OPERATIONS ASSUMPTIONS (CONT)

- ASSUME THREE CLASSES OF CUSTOMERS:
  - CLASS 1 - EXPERIMENT OWNER HAS OPERATIONS AND DATA PROCESSING FACILITIES AND PARTICIPATES IN MISSION OPERATIONS
  - CLASS 2 - EXPERIMENT OWNER HAS PASSIVE OPERATIONS WITH NO REAL TIME OPERATIONS (MAY COLOCATE AT CC FACILITIES)
  - CLASS 3 - USER OF EXPERIMENT FACILITY OR DATA BUT DOES NOT OWN EXPERIMENT ITSELF

- CREW TRAINING/PROCEDURES ARE SHARED RESPONSIBILITY:
  - CUSTOMER: EXPERIMENT OPERATIONS AND OBSERVATIONS
  - CC: CDSF SUBSYSTEMS OPERATIONS
  - NASA: ANY STS FLIGHT DECK, DOCKING, REMOTE MANIPULATOR SYSTEM, OR EXTRA VEHICULAR ACTIVITY

- UNIQUE ASPECTS OF MATERIALS PROCESSING EXPERIMENT OPERATIONS
  - EXPERIMENT OPERATIONS NOT "TARGET" OR TIME DEPENDENT LIKE SOLAR, EARTH SCIENCE, AND ASTRONOMY - FEW SCHEDULING CONSTRAINTS EXCEPT POWER, THERMAL RESOURCES
  - IN GENERAL, MATERIALS PROCESSING EXPERIMENTS CAN NOT BE STOPPED ONCE THEY ARE STARTED
  - VIDEO RECORDS CAN BE CRITICAL TO SOME EXPERIMENTS

- CC PREPARES AND DELIVERS CDSF ANCILLARY DATA TO CUSTOMER
  - POWER
  - THERMAL
  - ATTITUDE CONTROL HISTORY
  - EVENT TIMELINES

FLIGHT OPERATIONS ASSUMPTIONS (CONT)

- CC OBTAINS AND PROVIDES PLANNING AND SCHEDULING DATA TO CUSTOMER
  - LINK SCHEDULES
  - ON-BOARD RESOURCE CONSTRAINTS
- CC PERFORMS PLANNING AND TECHNICAL WORK FOR CDSF AND CUSTOMERS FOR STS OPERATIONS
- CC PROVIDES ELECTRONIC INTERFACES TO AND FROM CUSTOMERS FOR:
  - PLANNING
  - TECHNICAL INFORMATION EXCHANGE
  - SCHEDULING
  - ACCOUNTING
  - STATUS AND DATA TRANSFER
- STS PAYLOAD SPECIALIST FOR CDSF OPERATIONS IS EITHER CC PROVIDED PERSON OR MAJOR CUSTOMER PERSON
- CREW SUPPORT IS SUFFICIENT TO MAN THE CDSF 24 HRS PER DAY IF REQUIRED

FLIGHT OPERATIONS DESCRIPTION

5 SCENARIOS CONCEIVED TO DESCRIBE CDSF FLIGHT OPERATIONS:

1. PLANNING AND SCHEDULING: CONSTRUCTING THE MISSION TIMELINE FOR STS OR FF MISSION IS A JOINT ACTIVITY BETWEEN NASA AND THE CDSF CONTRACTOR AND BETWEEN THE CDSF CONTRACTOR AND THE CUSTOMERS.

2. THE STS MISSION WITH CREW OPERATIONS AND ORBITER DATA INTERFACES

3. THE FREE FLYER MISSION USING DIRECT LINKS TO THE TDRS

4. THE SERVICING MISSION INVOLVING CHANGEOUT OF EXPERIMENTS OR OTHER COMPONENTS AND REPLENISHING CONSUMABLES.

5. THE GROUND DATA HANDLING, EITHER MISSION, INVOLVES EXTENSIVE INTERFACES TO BOTH PUBLIC TELECOMMUNICATIONS SERVICES AND NASCOM. DATA PROCESSING IS PERFORMED BY THE CDSF CONTRACTOR AND DISTRIBUTED IN VARIOUS FORMS AND DIFFERENT SCHEDULES TO THE CUSTOMERS.

MISSION OPERATIONS DEFINITIONS

- TWO MISSIONS DEVELOPED FOR MISSION DATA HANDLING SYSTEM CONCEPT ASSESSMENT

  - STS MISSION WITH CREW TENDED OPERATIONS
  - LOW EARTH ORBIT (LEO) FREE FLYER (FF) MISSION

- ACTUAL MISSION COULD BE EITHER THE STS OR FF ONLY OR BOTH IN ONE MISSION

- CREW AND OPERATIONS PERSONNEL TRAINING AND PRE-LAUNCH INTEGRATION ACTIVITIES NOT INCLUDED IN THE SCENARIO

- MISSION PHASES ARE DIVIDED INTO THE FIVE OPERATIONS SCENARIOS DESCRIBED BELOW:

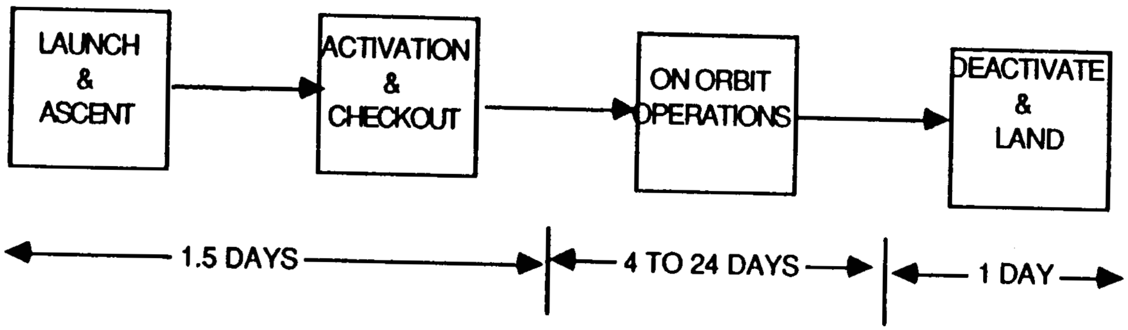
  1. PLANNING AND SCHEDULING
  2. STS/CDSF MISSION
  3. FF MISSION
  4. CDSF SERVICING
  5. GROUND DATA HANDLING

CDSF MISSION SEQUENCES

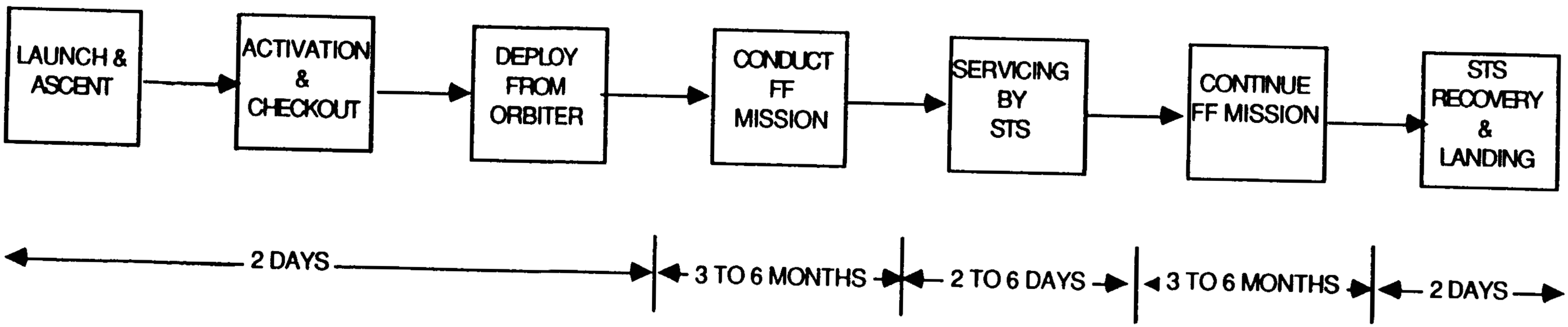
SHOWN HERE IS THE BASIC SEQUENCE OF A CDSF STS AND FREE FLYER MISSION. THE STS MISSION ON-ORBIT EXPERIMENT OPERATIONS LASTS FROM 4 TO 24 DAYS AND THE FF MISSION CONSISTS OF 3 TO 6 MONTH INCREMENTS WITH A SERVICING MISSION IN BETWEEN.

CDSF MISSION SEQUENCES

STS MISSION



FREE FLYER MISSION



FLIGHT OPERATIONS FUNCTIONS

THE FOLLOWING PAGES DESCRIBE THE FLIGHT OPERATIONS FUNCTIONS TO BE PERFORMED FOR EACH OF THE 5 MISSION PHASES OF A CDSF MISSION. MISSION PHASE 2 UNIQUELY DESCRIBES A CDSF/STS CREW-TENDED MISSION AND MISSION PHASE 3 UNIQUELY DESCRIBES A FREE FLYER (FF) MISSION. THE DEFINITION OF A FF MISSION PHASE FOLLOWING A CDSF/STS MISSION PHASE IS FOR REPORTING CONVENIENCE ONLY. FOR ANY GIVEN MISSION DESCRIPTION THEY MAY BE EITHER EXCLUDED OR COMBINED IN ANY ORDER OF ONE FOLLOWING THE OTHER. THE PURPOSE OF DEFINING THESE OPERATIONS FUNCTIONS IS TO PROVIDE MODELS FOR CDSF MISSION COMMUNICATIONS, COMMAND CONTROL AND DATA HANDLING SUPPORT WHICH IS TO BE PROVIDED BY THE MISSION DATA HANDLING SYSTEM (MDHS)CONCEPT TO BE DESCRIBED IN THE FOLLOWING SECTION 9.3.

FLIGHT OPERATIONS FUNCTIONS

1. PLANNING AND SCHEDULING

- CC TRANSMITS SCHEDULE FRAMEWORK TO CUSTOMERS APPROXIMATELY SIX MONTHS PRIOR TO LAUNCH INCLUDING:
    - FLIGHT RESOURCE PROFILES
    - CONSTRAINTS
    - PRELIMINARY COMMAND and DOWNLINK WINDOWS
- CUSTOMERS SUBMIT OPERATIONS REQUESTS IN TERMS OF RUN TIME AND CONSTRAINTS
- CC NEGOTIATES AND ITERATES CDSF MISSION TIMELINE INTO FINAL FORM AND NEGOTIATES STS SUPPORT TIMELINE WITH NASA
- CC DISTRIBUTES MISSION TIMELINE TO CUSTOMERS WITH PRIVACY FOR COMMERCIAL CUSTOMERS IF REQUESTED
- CC BUILDS COMMAND AND TIMELINE FILES TO VERIFY WITH CDSF SOFTWARE SIMULATOR
- FLIGHT SOFTWARE, INCLUDING SOME AUTOMATED TIMELINE FILES, IS BUILT AND LOADED INTO CDSF PROCESSOR PRIOR TO LAUNCH
- CUSTOMER IS RESPONSIBLE FOR ANY EXPERIMENT PROCESSOR SOFTWARE

FLIGHT OPERATIONS FUNCTIONS (CONT)

2. STS/CDSF MISSION OPERATIONS

- CDSF ACTIVATED FROM ORBITER AFT FLIGHT DECK
  - CDSF CREWMAN ENTERS AND CONTINUES CDSF ACTIVATION AND CHECKOUT AND LOADING AND ACTIVATION OF EXPERIMENTS
  - OPERATIONS SUPPORTED BY CUSTOMERS VIA VOICE LOOP AND REAL TIME DATA LINKS, INCLUDING CCTV VIDEO IF REQUIRED.
- EXPERIMENT HOUSEKEEPING DATA AND QUICK LOOK SCIENCE DATA IS LEVEL 0 PROCESSED AT CC DATA PROCESSING FACILITY (DPF) AND RELAYED TO CUSTOMER
- EXPERIMENT OPERATIONS PROCEED IN SEVERAL MODES:
  - AUTOMATIC TIMELINE EXECUTION FROM CDSF PROCESSOR
  - CREWPERSON HANDS-ON
  - CREWPERSON AND CUSTOMER VIA REAL TIME DATA, CCTV AND VOICE LINKS
  - CUSTOMER OF FCC GENERATED GROUND COMMANDS

FLIGHT OPERATIONS FUNCTIONS (CONT)

3. FREE FLYER MISSION OPERATIONS

   - PLANNING AND SCHEDULING PROCESS

     - SIMILAR TO STS MISSION

     - DONE IN 1 WEEK SEGMENTS THAT ARE ITERATED CONTINUOUSLY DURING THE FF MISSION

   - CDSF SUBSYSTEMS AND SOME EXPERIMENTS CHECKED WHILE STILL ATTACHED TO ORBITER

   - CDSF POWER DOWN FOR DEPLOYMENT

   - CDSF DEPLOYED FROM ORBITER AND POWERED UP

   - EXPERIMENTS PROCEED WITH COMBINATION OF ONBOARD CDSF OR EXPERIMENT PROCESSOR COMMANDS AND GROUND COMMANDS GENERATED BY FCC OR CUSTOMERS

   - FOR SOME EXPERIMENTS LIVE VIDEO IS UTILIZED AT THE CUSTOMERS FACILITY TO EXAMINE EXPERIMENT INTERIM OR FINAL RESULTS AND MAKE OPERATIONAL ADJUSTMENTS

FLIGHT OPERATIONS FUNCTIONS (CONT)

- ALL CDSF SUBSYSTEM COMMAND AND CONTROL PERFORMED BY CREW PERSON, ON BOARD PROCESSOR OR FCC OPERATORS
- ANY CUSTOMER GENERATED COMMANDS SENT THROUGH CC FCC FOR CURSORY AUTHENTICATION AND FORWARDING TO NASA JSC/MCC
    - MCC FORWARDS THESE OR STORED CDSF COMMANDS TO THE ORBITER/CDSF
- CUSTOMERS, CREW PERSON AND FCC PERSONNEL COORDINATE TO MODIFY TIMELINE IN CASE OF EQUIPMENT FAILURES OR UNEXPECTED RESULTS
- EXTRA SAMPLES AND SPECIMENS ARE ON BOARD TO FILL IN ANY UNEXPECTEDLY AVAILABLE TIME FOR EXPERIMENTS TO PERFORM ADDITIONAL OPERATIONS
- FCC COMMUNICATES WITH VOICE AND DATA TO STS MISSION CONTROL CENTER (MCC) TO COORDINATE COMMUNICATIONS, THRUSTER ACTIVITY, AND OTHER SUPPORT
- AT THE END OF MISSION THE CDSF IS CLOSED OUT FOR DEORBIT AND LANDING
- DELIVERY OF EXPERIMENT SAMPLES FROM THE STS LANDING SIGHT PROVIDED AS AN OPTIONAL SERVICE
- NORMAL DEINTEGRATION OF CDSF PERFORMED AT CDSF I&T FACILITY WITHIN TWO WEEKS

FLIGHT OPERATIONS FUNCTIONS (CONT)

4. CDSF SERVICING

- ALL EXPERIMENT AND SUBSYSTEM HARDWARE TO BE INSTALLED IN THE CDSF HAS BEEN FIT CHECKED IN CC CDSF INTERIOR HI FIDELITY MOCKUP

- CDSF IS DEACTIVATED TO A SAFE STATE FOR DOCKING:

    - ALL BUT MANDATORY EXPERIMENT POWER IS OFF

    - SUBSYSTEMS ARE IN STANDBY MODES

    - SOLAR ARRAYS MAY BE FOLDED FOR DOCKING

    - CONTINGENCY EVA AVAILABLE IF DOCKING FAILS

- STS IS LAUNCHED WITH CDSF LOGISTICS MODULE IN CARGO BAY

- STS ARRIVES ON STATION WITH THE CDSF IN LEO

- STS MANEUVERS AND DOCKS CDSF AND LOGISTICS MODULE WITH POSSIBLE EVA ASSISTANCE.

FLIGHT OPERATIONS FUNCTIONS (CONT.)

5. GROUND DATA HANDLING SCENARIO

% CDSF DATA CAPTURED AT TDRSS/NASA GROUND TERMINAL (NGT) FOR ALL MISSION PHASES

- STS MISSION: DATA COMES TO CC DPF VIA JSC AFTER DOCUMENTATION FROM STS DATA
- FF MISSION: DATA COMES TO CC DPF DIRECT FROM NGT (OR FROM GSFC) VIA LANDLINE OR DOMSAT HIGH RATE TRANSPONDER

% CC DPF SEPARATES AND SENDS DATA TO CUSTOMERS IN REAL TIME

- LIVE DATA AND PROCESSED PLAYBACK DATA
- EXPERIMENT STREAMS AND/OR CDSF ENGINEERING DATA
- STS VOICE AND CCTV VIDEO

% CDSF ENGINEERING DATA DISPLAYED, LIMIT CHECKED IN FCC

% DPF BEGINS PROCESSING ALL DATA TO LEVEL 0

% PROCESSED DATA DELIVERED TO CUSTOMERS VIA COMMERCIAL PACKET NETS, SATELLITE PATHS AND MAGNETIC TAPE

- EXPERIMENT DATA STREAMS
- CDSF ENGINEERING DATA
- CDSF ANCILLARY DATA
- STS ENGINEERING DATA (OPTIONAL)

% DPF PERFORMS ACCOUNTING FUNCTION

- DATA QUALITY RECORDS
- TELECOMM COSTS
- STORAGE AND PROCESSING PROVIDED

FLIGHT OPERATIONS FUNCTIONS (CONT)

- CUSTOMER COMMANDS ARE SENT TO THE CC FCC FOR CURSORY AUTHENTICATION AND FORWARDING TO GODDARD SPACE FLIGHT CENTER

- EXPERIMENTERS AND FCC PERSONNEL COORDINATE TO PERFORM PREDEFINED OBJECTIVES AS WELL AS REAL TIME CHANGES REQUIRED IN CASE OF EQUIPMENT FAILURES OR UNEXPECTED RESULTS

- FCC COORDINATES ALL TDRSS AND NASCOM SUPPORT AS WELL AS ROUTING OF REAL TIME DATA TO CUSTOMERS

- FCC PLANNING AND SCHEDULING FUNCTION CONTINUES BUILDING TIMELINE SEGMENTS IN ADVANCE OF MISSION PHASES AS THE MISSION PROCEEDS

- CC PERSONNEL CONDUCT PLANNING AND TECHNICAL INTERFACE WORK WITH THE STS FOR THE FIRST SERVICING MISSION SCHEDULED FOR 4 MONTHS INTO THE FF MISSION

- CDSF HAS CONSUMABLES FOR AN ADDITIONAL 3 MONTHS BEYOND THE PLANNED SERVICING MISSION DATE

- BATTERY BACKUPS ARE FURTHER PROVIDED FOR HEATERS OR OTHER APPARATUS THAT WOULD BE REQUIRED TO PRESERVE SAMPLES SHOULD THE SOLAR POWER SYSTEM FAIL

FLIGHT OPERATIONS FUNCTIONS (CONT)

- CREWPERSON ENTERS AND BEGINS SAMPLE AND EXPERIMENT EXCHANGES
  - ALL SERVICING OPERATIONS CONDUCTED BY NASA ARE ASSISTED BY CDSF FCC AND CUSTOMER PERSONNEL
  - DATA, VOICE AND CCTV LINKS ARE PROVIDED BETWEEN MCC, FCC AND CUSTOMERS
  - SOME CUSTOMERS ARE IN FCC FOR SERVICING OPERATION
- FIVE PERSON CDSF TEAM IS AT MCC FOR SERVICING OPERATION
  - EXTENSIVE USE OF A DISTRIBUTED ENGINEERING DATA BASE AND A COMMON SET OF COLOR PHOTOGRAPHS IS UTILIZED BETWEEN CDSF CC PERSONNEL AND CUSTOMERS TO ENSURE THAT SERVICING OPERATION IS COMPLETED SUCCESSFULLY
- CLOSE OUT PICTURES TAKEN TO VERIFY SWITCH POSITIONS, SAMPLE OR CARTRIDGE STATUS, POSITIONS, ETC
- CDSF IS ACTIVATED FOR POST SERVICING CHECKS FROM THE FCC
- CDSF IS DEACTIVATED AND DEPLOYED FROM ORBITER CARGO BAY
  - VARIATIONS ARE PERFORMED FOR SPECIAL EXPERIMENTS
- CDSF IS ACTIVATED AND FF MISSION RESUMES

9.3. MISSION DATA HANDLING SYSTEM (MDHS) CONCEPT

CDSF MISSION DATA HANDLING SYSTEM CONCEPT DEVELOPMENT PROCESS

THE CDSF MISSION DATA HANDLING SYSTEM (MDHS) IS DEFINED TO CONSIST OF THE (1)CDSF ON-BOARD MDHS, (2) THE GROUND MDHS AND (3) THE COMMUNICATIONS NETWORK. THE COMMUNICATION CONSISTS OF TWO SEGMENTS - THE SPACE SEGMENT AND THE GROUND SEGMENT. THE SPACE SEGMENT CONSISTS OF THE LINK BETWEEN THE CDSF AND THE NASA TRACKING AND DATA RELAY SATELLITE (TDRSS). THE GROUND SEGMENT CONSISTS OF THE NETWORK TO HANDLE DATA TO AND FROM THE TDRSS WHICH CONSISTS OF BOTH EARTH AND SPACE NETWORKS.

FOR THE FUNCTIONS OF THE 5 MISSION PHASES OF A CDSF MISSION DESCRIBED IN THE PREVIOUS SECTION 9.2, THE PROCESS FOR DEVELOPING THE CDSF MDHS CONCEPT IS SHOWN FOR BOTH THE FLIGHT ON-BOARD MDHS AND THE GROUND MDHS. SINCE, AS PREVIOUSLY DESCRIBED, PHASE 2 IS DEFINED AS A CDSF/STS MISSION OPERATIONS SCENARIO, A MODEL OF TYPICAL CDSF OPERATIONAL FUNCTIONS HAD TO BE DEVELOPED TO DEFINE STS PAYLOAD INTERFACE DESCRIPTIONS. SINCE CDSF/STS MISSIONS WILL BE CONTROLLED AT THE JSC MISSION CONTROL CENTER, COMPLETE MISSION OPERATIONS PLANS ARE REQUIRED AND MUST BE CONSIDERED FOR SUPPORT BY THE CDSF MDHS.

FOR THE FUNCTIONS OF A PHASE 3 FREE FLYER MISSION THE DEVELOPMENT OF THE MISSION EXPERIMENT MODEL OF SECTION 9.1 IS USED AS A DATA HANDLING SYSTEM SIZING MODEL FOR BOTH THE ON BOARD AND GROUND MDHS ELEMENTS.

CDSF GROUND DATA HANDLING ANALYSIS PROCESS

	1	2	3	4	5
FLIGHT MDHS	STUDY EXPERIMENT CANDIDATES	SIZE SUBSYSTEMS DATA REQTS	BUILD SAMPLE CDSF TIMELINE	DERIVE DATA QUANTITIES, RATES	ASSESS ON BOARD MDHS
	ASSESS MATERIALS PROCESSING EXPT FUTURE PLANS	BUILD MODEL OF TYPICAL CDSF PAYLOAD	ASSESS ON BOARD MDHS	ASSESS ON BOARD MDHS	
	ASSESS CDSF SYSTEMS CONCEPTS	DERIVE MISSION OPS CONCEPT			
		DERIVE DATA TYPES			
GROUND MDHS		DERIVE MISSION GROUND CONCEPTS	DERIVE FACILITY OPERATIONS CONCEPTS, REQTS	DERIVE GROUND DATA DISTRIBUTION ARCHITECTURE	DERIVE GROUND PROCESSING, STORAGE, COMM. REQUIREMENTS
				ASSESS PUBLIC AND NASCOM CAPABILITIES	ESTIMATE ROM COSTS OF CDSF GROUND SYSTEMS

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9.3.1 CDSF ON-BOARD MDHS SYSTEM CONCEPT

ON BOARD MDHS REQUIREMENTS SUMMARY.

THE NEXT 3 PAGES LIST TOP LEVEL FUNCTIONAL REQUIREMENTS FOR THE CDSF ON BOARD MDHS. THEY ARE BASED ON THE EXPERIMENT MISSION MODEL TIMELINE DEVELOPED IN SECTION 9.1 AND DERIVED MISSION OPERATIONS SUPPORT SCENARIOS DEVELOPED IN SECTION 9.2. THE REQUIREMENTS ARE FOR BOTH STS AND FREE FLYER MISSION MODES. SOME OF THE DERIVED NON STANDARD REQUIREMENTS TO BE STUDIED FURTHER ARE: DATA PROCESSING OR COMPRESSION; VIDEO SWITCHING; VIDEO RECORDING; ERROR CORRECTING; ENCRYPTION OF PROPRIETARY DATA (OR LEFT TO CUSTOMER).

ON BOARD MISSION DATA HANDLING SYSTEM (MDHS) FUNCTIONAL REQUIREMENTS

- COLLECT AND DOWNLINK EXPERIMENT DATA
    - REAL TIME AND DELAYED PLAYBACK
    - HIGH RATE AND LOW RATE DIGITAL
    - ANALOG
- STORE EXPERIMENT AND SUBSYSTEM DATA BETWEEN LINKS AND AS BACKUP TO LIVE DOWNLINK DATA
- COLLECT STORE, DOWNLINK APPROXIMATELY 20 KPS CONTINUOUS SUBSYSTEM DATA
- PROVIDE ERROR DETECTION ENCODING
- PROVIDE MAN MACHINE INTERFACE FOR MAN TENDED OPERATIONS FOR:
    - CONTROL AND MONITOR OF CDSF SUBSYSTEMS
    - CONTROL AND MONITOR OF EXPERIMENTS (OPTIONAL)
- ACCEPT, AUTHENTICATE AND DISTRIBUTE COMMAND OR PROCESSOR FILES TO EXPERIMENTS
- ACCEPT AND PROCESS SUBSYSTEM COMMANDS FOR GROUND CONTROL OF SUBSYSTEMS

ON BOARD MISSION DATA HANDLING SYSTEM (MDHS) FUNCTIONAL REQUIREMENTS

- ACCEPT FLIGHT PROCESSOR SOFTWARE UPLOADS AND MEMORY DUMPS
- ACCEPT AND DISTRIBUTE GPS (OR INTERNALLY GENERATED) TIMING DATA FOR SUBSYSTEM AND EXPERIMENT USE
- PROVIDE MASS MEMORY FOR SUBSYSTEM AND EXPERIMENT SOFTWARE STORAGE
- FAULT MANAGEMENT AND CAUTION AND WARNING FUNCTIONS
- CDSF SYSTEM MONITOR AND SWITCHOVER SOFTWARE
- REDUNDANT DATA MANAGEMENT CAPABILITY

ON BOARD MISSION DATA HANDLING SYSTEM (MDHS) FUNCTIONAL REQUIREMENTS

- DATA INTERFACE COMPATIBILITY WITH THE STS FOR CDSF/STS MISSIONS INCLUDE:
  - AFT FLIGHT DECK HARDLINES AND/OR ORBITER COMPUTER DATA INTERFACES
  - NETWORK SIGNAL PROCESSOR
  - KU BAND SIGNAL PROCESSOR
  - ORBITER VIDEO UNIT
  - ORBITER INTERCOM
- FOR FF MISSIONS, TDRS COMPATIBLE RF EQUIPMENT-SIGNAL PROCESSORS, TRANSPONDERS, ANTENNAS

ON BOARD MDHS CHARACTERISTICS

THE CHARACTERISTICS OF THE VARIOUS DATA TYPES AND RATES GENERATED ON BOARD THE CDSF ARE LISTED ON THE FOLLOWING 4 PAGES. A SUBSYSTEM DATA RATE IS DETERMINED (16 KBPS) AND EXPERIMENT DATA RATES ARE LISTED. STANDARD DATA AND VIDEO RATES ARE DESCRIBED TO ACCOMMODATE THE CDSF CANDIDATE EXPERIMENTS DEFINED IN SECTION 9.2.1.

ON BOARD MISSION DATA HANDLING SYSTEM (MDHS) DATA CHARACTERISTICS

- CDSF SUBSYSTEM DATA RATE IS ESTIMATED AT 16 KBPS AVERAGE:

  - SUBSYSTEM DATA RATE ESTIMATE BASED ON SIMILAR SPACECRAFT (SPACELAB, GRO, UARS, SPACE TELESCOPE) AND DESIGNS AND ADJUSTMENT FOR SMART DATA COLLECTION.

- CDSF SUBSYSTEM DATA COLLECTION CONSISTS OF:

  1. DATA MANAGEMENT:
     - BLACK BOX TEMPERATURES
     - POWER SUPPLY VOLTAGES AND CURRENTS
     - MULTIPLEXOR FORMATS (IF APPLICABLE)
     - NETWORK INFORMATION (IF APPLICABLE),ETC.

  2. COMMUNICATIONS SYSTEM (TT&C):
     - BLACK BOX TEMPERATURES
     - POWER SUPPLY VOLTAGES AND CURRENTS
     - TRANSMITTER MODES
     - AMPLIFIER OUTPUTS AND TEMPERATURES
     - ANTENNA MODES
     - SIGNAL STRENGTH MEASUREMENTS
     - TAPE RECORDER MODES AND POSITION INDICATIONS; ETC.

ON BOARD MISSION DATA HANDLING SYSTEM (MDHS) DATA CHARACTERISTICS

3. THERMAL:
   - PUMP TEMPERATURES
   - RPMS, AND STATUS
   - STRUCTURAL AND COLDPLATE TEMPERATURE TRANSDUCERS
   - VALVE STATUS
   - FLOW TRANSDUCERS
   - RADIATOR AND HEAT EXCHANGER TEMPERATURE TRANSDUCERS

4. POWER:
   - ALL BUS VOLTAGES AND CURRENTS
   - RELAY POSITIONS
   - BATTERY VOLTAGES AND CHARGING CURRENTS
   - VOLTAGE REGULATOR OUTPUTS
   - CONVERTER VOLTAGES AND CURRENTS
   - SOLAR ARRAY TEMPERATURES/POSITIONS/OUTPUTS
   - CIRCUIT BREAKER POSITIONS

5. PROCESSORS AND MASS MEMORY:
   - TEMPERATURES
   - POWER SUPPLY VOLTAGES AND CURRENTS
   - OPERATIONAL INDICATIONS
   - READ/WRITE INDICATIONS
   - REGISTER AND MEMORY CONTENTS
   - INTERRUPT AND ERROR MESSAGES

ON BOARD MISSION DATA HANDLING SYSTEM (MDHS) DATA CHARACTERISTICS

6. GUIDANCE AND CONTROL SYSTEM (FF MISSION ONLY):
   - GYRO AND ACCELEROMETER ENGINEERING DATA AND OUTPUTS
   - THRUSTER FIRINGS
   - ATTITUDE INFORMATION AND ERROR SIGNALS.

- SINGLE EXPERIMENT PCM DATA FROM 100 BPS TO 32 KBPS
- EXPERIMENT DIGITAL HIGH RATE VIDEO DATA FROM LESS THAN 1MBPS TO 67 MBPS. ASSUMED FOR PURPOSES OF GROWTH ONLY.
- EXPERIMENT 4.25 MHZ ANALOG VIDEO
- CCTV 4.25 MHZ VIDEO (STS MISSION ONLY).
- UPLINK COMMAND DATA CONSISTING OF LOW RATE PCM, 2 TO 25 KBPS, COMPUTER FILES AND MEMORY LOADS
- CDSF COMPOSITE DATA RATE WOULD VARY FROM 16 KBPS TO SHORT PERIODS OF UP TO 45 MBPS OR MORE

CDSF ON BOARD MDHS INTERFACE DESCRIPTIONS

THE CAPABILITIES OF THE CDSF SPACE SEGMENT DATA COMMUNICATIONS LINKS ARE DESCRIBED. TWO CDSF INTERFACES ARE DEFINED. THE CDSF/STS HAS A HARDWARE INTERFACE WHICH HAS THE CHARACTERISTICS AS DESCRIBED. THE CDSF INTERFACE TO THE MDHS GROUND SEGMENT UTILIZES THE TDRSS LINK WITH THE DESCRIBED CAPABILITIES.

ON BOARD MISSION DATA HANDLING SYSTEM (MDHS) INTERFACE DESCRIPTIONS

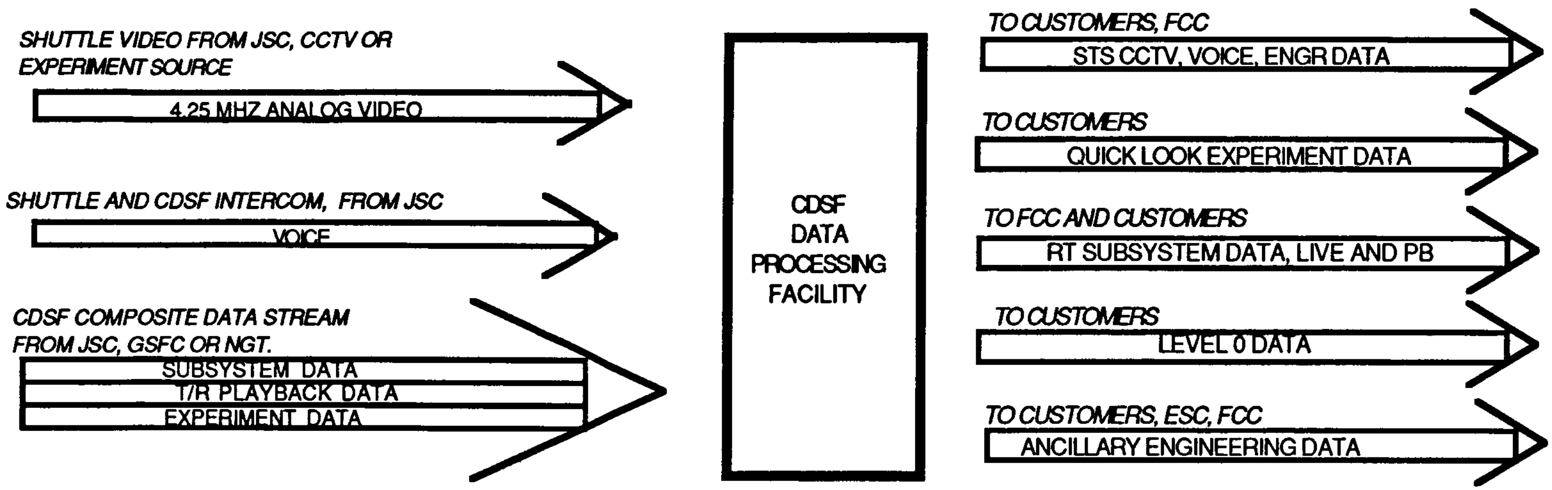
- STS HARDLINE INTERFACE CAPABILITIES:
  - S BAND SIGNAL PROCESSOR
    - 300 HZ TO 4 MHZ ANALOG / 200 KBPS TO 5 MBPS DATA/ UP TO 64 KBPS UPLINK. (ASSUMES THAT 128KBPS DOD INTERFACE NOT AVAILABLE TO PRIVATE CUSTOMER)
  - KU BAND SIGNAL PROCESSOR
    - UP TO 50 MBPS DATA AND NO ANALOG VIDEO OR UP TO 1.024 MBPS DATA AND 4.5 MHZ VIDEO. UPLINK BW IS UP TO 128 KBPS
  - KU BAND LINK UTILIZES THE STANDARD STS PAYLOAD INTERFACE AS SPACELAB.
    - IT ALLOWS ENOUGH BANDWIDTH FOR CDSF DATA AND VIDEO THAT IS EITHER 4.5 MHZ ANALOG OR DIGITAL UP TO 50 MBPS
- CDSF DIRECT TO TDRS CAPABILITIES:
  - ALLOWS THE CDSF TO COMMUNICATE DIRECTLY TO THE TDRS
  - BANDWIDTH FROM A FEW KBPS TO 300 MBPS .
  - TDRS DIRECT MODE NOT USED DURING ATTACHED OR PROXIMITY OPERATIONS WITH THE ORBITER DUE TO INTERFERENCES.

CDSF DATA TYPE DESCRIPTION

A CDSF MISSION TIMELINE FOR ONE DAY WAS DERIVED IN SECTION 9.1 TO MAKE A THOROUGH DATA SIZING STUDY FOR THE ON-BOARD CDSF MDHS. THE DATA COMPILATION RESULTS OF THIS STUDY ARE SHOWN ON THE FOLLOWING 3 PAGES AND INCLUDE DAILY VOLUMES AND RATES FOR THE CDSF TOTAL (ROW 18 AND 36), EXPERIMENT TOTAL VOLUMES (COLUMN 27). TAPE RECORDER USAGE IS SHOWN IN ROWS 21 TO 24 AND LINK TIMES AND BANDWIDTHS SHOWN IN ROWS 26 THROUGH 31). EXPERIMENT VIDEO RATES ARE CONSISTENT WITH DATA RATES LISTED FOR THE CANDIDATE CDSF EXPERIMENTS LISTED IN SECTION 4.2.1.

THE DIAGRAM DESCRIBES THE CDSF DATA TYPES AND DEFINES THE DATA TYPES AS SUBSYSTEM DATA, EXPERIMENT QUICK LOOK DATA, TAPE RECORDER PLAYBACK DATA AND EXPERIMENT NON-REAL TIME DATA. THE 2ND AND 3RD PAGES QUANTIFY THESE DATA SOURCE VOLUMES AND RATES FOR TAPE RECORDER AND LINK TIMES/BANDWIDTHS OPERATIONS MENTIONED.

CDSF DATA TYPES



DATA DEFINITIONS

SUBSYSTEM DATA

- THERMAL, POWER, GUIDANCE, DATA MANAGEMENT, COMM. ETC, SUBSYSTEM DATA.
- GOES TO FCC DISPLAYS IN REAL TIME FOR HEALTH AND STATUS MONITOR.
- GOES TO ESC FOR PERF. ANALYSIS
- SOME GOES TO ANCILLARY DATA PROCESSING

T/R PLAYBACK DATA

- DATA COLLECTED BY ON BOARD RECORDER BETWEEN DOWNLINKS OR DURING DOWNLINKS TO BACKUP LIVE DATA FOR EXPERIMENTS.
- CONSISTS OF PRIORITY AND ROUTINE DATA
- REQUIRES REVERSAL PROCESSING BEFORE GOING TO FCC, CUSTOMERS IN REAL TIME AND LEVEL 0 PROCESSING.

EXPERIMENT QUICK LOOK DATA

- ENGINEERING DATA (TEMPERATURES, STATUS, ETC.) USED BY CUSTOMER TO MONITOR HEALTH AND STATUS OF EXPERIMENTS.
- APPROX. 10% OF ALL EXPERIMENT DATA
- GOES TO CUSTOMER FROM DPF, IN REAL TIME, WITHOUT LEVEL 0 PROCESSING.

EXPERIMENT NON REAL TIME DATA

- SCIENCE ORIENTED DATA NOT REQUESTED IN REAL TIME.
- LEVEL 0 PROCESSED
- DELIVERED TO CUSTOMER FROM NEAR REAL TIME TO 7 DAYS.

DATA TABLE FROM SAMPLE MISSION

DATA SOURCES	HOUR 1	2	3	4	5	6	7	8	9	10	11	12
	DATA RATE (mbps)											
SUBSYSTEMS	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
EXPT 1	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
2	1.5025	1.5025	1.5025	1.5025	1.5025	1.5025	1.5025	1.5025	1.5025	1.5025	1.5025	1.5025
3	0.02	10.02	0.02	10.02	10.02	10.02	10.02	0.02	0.02			
4										0.001	0.001	0.001
5										0.032	0.032	0.032
6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
7												
8												
9	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
10	0.0002	0.0002	0.0002	0.0002	0.0002							
11												
12	25.0001	0.0001	25.0001	0.0001	25.0001	0.0001	25.0001	0.0001	25.0001	0.0001	25.0001	0.0001
Total Rate (mbps)	26.6443	11.6443	26.6443	11.644	36.6443	11.6441	36.6441	1.6441	26.6441	1.6571	26.6571	1.6571
Total data (mb)	95919	41919	95919	41919	131919	41919	131919	5919	95919	5966	95966	5966
Cum Data (Gb)	95.92	137.84	233.76	275.68	407.60	449.52	581.43	587.35	683.27	689.24	785.20	791.17
TAPE RECORDER												
ON T/R (Gb)	96	138	0	0	0	0	132	138	234			
T/R PB VOL. (Gb)			34	34	34	34				58	58	58
T/R PB RATE (mbps)			9.57	9.57	9.57	9.57				16.23	16.23	16.23
LINKS												
DOWNLINK VOL (mb)			130379	76379	166379	76379				64405	154405	64405
LINK NO.			1	1	1	1				2	2	2
LINK BW (mbps)			36	21	46	21				18	43	18
TIME(mins)			60	60	60	60				60	60	60
TOTAL DL (mb)			130379	206758	373138	449516	449516.2	449516.2	449516.2	513920.79	668325.4	732730.05
DAY TOTALS												
LIVE DATA (Gb)	719.9672											
PB DATA (Gb)	693.5886											
ALL DATA (Gb)	1413.556											

NOTES:
1. LINKS ARE CONSTANT BW WITH FILL DATA ADDED TO CDSF DATA.
2. TAPE RECORDER PLAYBACK DATA IS MULTIPLEXED TOGETHER WITH LIVE DATA FOR TOTAL DOWNLINK BW.
3. ALL TIMELINE EVENTS ARE IN INCREMENTS OF ONE HOUR.
4. LINK BW'S CONSTRAINED TO <45 MBPS

DATA TABLE FROM SAMPLE MISSION

DATA SOURCES	MISSION HOUR 13	14	15	16	17	18	19	20	21	22	23	24	TOTAL SOURCE DATA VOL. (mb)
DATA RATES (mbps)													
SUBSYSTEMS	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	1728
EXP'T 1	0.0005	1.5005	1.5005	1.5005	1.5005	1.5005	1.5005	1.5005	1.5005	0.0005	0.0005	0.0005	43243
2	1.5025	1.5025	1.5025	1.5025	1.5025	1.5025	0.0025	0.0025	0.0025	0.0025	0.0025	0.0025	97416
3													180648
4	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	54
5	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	0.032	1728
6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	8640
7													0
8													0
9	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	86
10													4
11													
12	25.0001	0.0001	25.0001	0.0001	25.0001	0.0001	25.0001	0.0001	25.0001	0.0001	25.0001	0.0001	1080009
Total Rate (mbps)	26.6571	3.1571	28.1571	3.1571	28.1571	3.1571	26.6571	1.6571	26.6571	0.1571	25.1571	0.1571	
Total data (mb)	95966	11366	101366	11366	101366	11366	95966	5966	95966	566	90566	566	1413556
Cum Data (Gb)	887.13	898.50	999.87	1011.23	1112.60	1123.96	1219.93	1225.89	1321.86	1322.42	1412.99	1413.56	
TAPE RECORDER													
ON T/R (Gb)		11	113	124			96	102	198				
T/R PB VOL. (Gb)	58				62	62				66	66	66	
T/R PB RATE (mbps)	16.23				17.24	17.24				18.32	18.32	18.32	
LINKS													
DOWNLINK VOL (mb)	154405				163414	73414				66531	156531	66531	
LINK NO.	2				3	3				4	4	4	
LINK BW (mbps)	43				45	20				18	43	18	
TIME(mins)	60				60	60				60	60	60	
TOTAL DL (mb)	887135	887135	887134.7	887134.7	1050549	1123962	1123962	1123962	1123962	1190494	1347025	1413556	
								720					
								694					
								1414					

CDSF ON BOARD MDHS FUNCTIONAL DIAGRAM

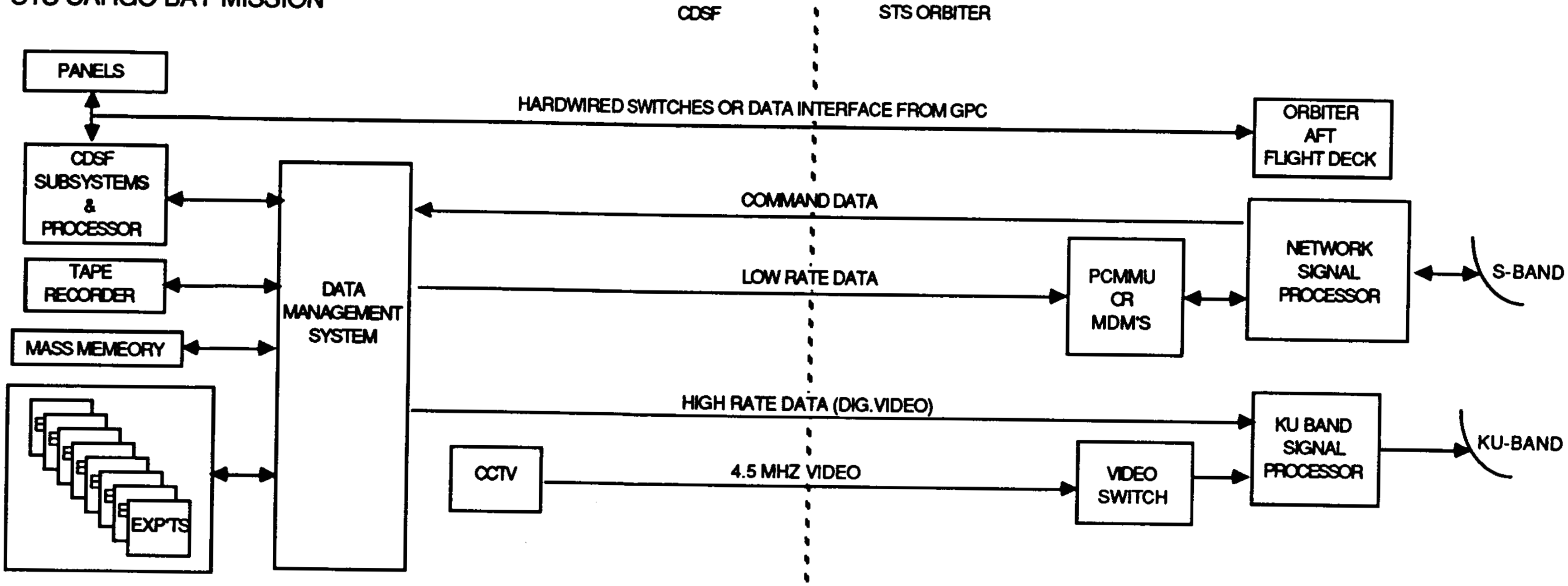
THE DEFINED CDSF DATA LINK INTERFACES TO THE SHUTTLE DURING THE STS MISSION AND THE DIRECT TDRS CONFIGURATION FOR A FREE FLYER MISSION ARE SHOWN. THE DATA MANAGEMENT BLOCK INCLUDES THE DATA BUS OR LAN, THE VIDEO PROCESSOR FOR COMPRESSION OR ANALOG TO DIGITAL CONVERSION. SHUTTLE COMPUTER (GPC) AND AFT FLIGHT DECK INTERFACES ARE THE MINIMUM REQUIRED FOR ACTIVATION, SAFETY CHECKS AND CAUTION AND WARNING FUNCTIONS. THE COMMUNICATIONS AND TRACKING HARDWARE (C&T) INCLUDES THE MUITIPLEXER, THE SIGNAL PROCESSORS, POWER AMPLIFIERS AND ANTENNA ASSEMBLIES. SHOWN SEPARATELY IS THE TAPE RECORDER, THE ON BOARD PROCESSORS AND THE DATA SOURCES.

THE LAN, DEFINED AS PART OF THE ON BOARD DATA MANAGEMENT BLOCK, IS KEY TO USER INTERFACE AND DATA MANAGEMENT FLEXIBILITY. A SMART PROCESSOR IS KEY TO REDUCING AUTOMATION COSTS. ON BOARD STORAGE IS CRITICAL FOR REDUCING LINK TIMES AND DATA COLLECTION BACKUP.

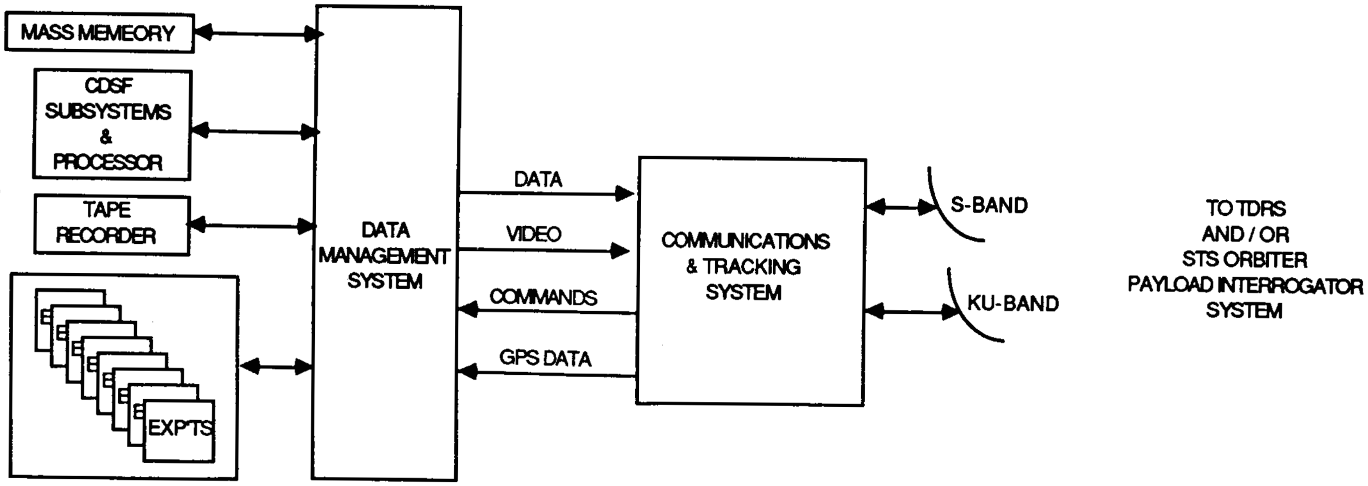
REQUIREMENTS FOR AN ADDITIONAL DATA STREAM MULTIPLEXER AND VIDEO SWITCH IN THE CDSF ON BOARD ARCHITECTURE AND SOME RECOMMENDATIONS FOR LOW DEVELOPMENT COST FLIGHT PROCESSORS WHILE NOT PART OF THIS CDSF SYSTEM DEFINITION SHOULD BE CONSIDERED: THE MOST VIABLE PROCESSOR SOLUTION MAY BE THE GRID 1137 COMPUTER FOR LOW AUTOMATED DESIGN AND A HARDENED VAX FOR GREATER CAPABILITY. ANOTHER OPTION WOULD BE A CUSTOM MACHINE(S) BASED ON A 80286 OR 80386 PROCESSOR. THIS OPTION ENTAILS MORE RISK AND EXPENSE HOWEVER.

CDSF ON BOARD MDHS OVERVIEW

STS CARGO BAY MISSION



FREE FLYER MISSION



C-7

NASA

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9.3.2 CDSF GROUND MISSION DATA HANDLING SYSTEM (MDHS) CONCEPT

CDSF GROUND MDHS ASSUMPTIONS

THIS SECTION DESCRIBES THE GROUND SYSTEM CONCEPT FOR THE CDSF MISSION DATA HANDLING SYSTEM. CONCEPTS FOR COMMUNICATIONS AND DATA NETWORKING ARE PRESENTED. A FUNCTIONAL CONCEPT FOR A CDSF MISSION OPERATIONS CONTROL CENTER IS DESCRIBED.

LISTED HERE ARE THE ASSUMPTIONS ABOUT THE CDSF CONTRACTOR (CC) GROUND OPERATIONS RESPONSIBILITIES VERSUS THOSE OF NASA.

GROUND MDHS ANALYSIS

GROUND MDHS ASSUMPTIONS

- NASA POLICY WOULD ALLOW THE CDSF CONTRACTOR TO LEASE GROUND PROCESSING SERVICE FROM A NASA CENTER AND TELECOMM FROM NASCOM
- CDSF CC DPF PROVIDES LEVEL 0 PROCESSING AS A STANDARD SERVICE BUT HIGHER LEVELS COULD BE DONE AS AN OPTIONAL SERVICE
- GROUND MDHS ANALYSIS PROCESS DESCRIBED IN SECTION 9.0.
- ALL CUSTOMER DATA HANDLING IS DONE BY THE CC
- COMPOSITE CDSF DATA TRANSPORT TO THE CC IS A JOINT NASA/CC ARRANGEMENT
- ALL MISSION OPERATIONS ARE PERFORMED BY THE CC FOR FREE FLYER MISSIONS

CDSF GROUND MDHS DATA DEFINITIONS AND CHARACTERISTICS

CDSF GROUND DATA FLOW CONSISTS OF FORWARD LOW RATE SHORT DURATION DATA AND HIGHER RATE, LONGER DURATION DATA IN THE RETURN LINKS. THE CDSF COMPOSITE RETURN DATA STREAM IS ENCAPSULATED IN THE STS DATA STREAM FOR THE NOMINAL STS MISSION CONFIGURATION AND IN TURN ENCAPSULATES CDSF COMPONENT DATA. LISTED HERE ARE THE DATA DESCRIPTIONS DEFINED TO BE PART OF THE RETURN LINKS.

CDSF GROUND MDHS DATA DEFINITIONS AND CHARACTERISTICS

- RETURN DATA
  - CDSF/STS AIR TO GROUND DATA CONSISTS OF:
    - CDSF COMPOSITE DATA
    - STS CCTV DATA
    - STS INTERCOM VOICE DATA
    - STS ENGINEERING DATA
  - CDSF FF AIR TO GROUND DATA CONSIST OF:
    - CDSF COMPOSITE DATA
  - CDSF COMPOSITE DATA CONSISTING OF:
    - LIVE AND TAPE RECORDER PLAYBACK DATA
    - CDSF SUBSYSTEM DATA
    - EXPERIMENT DATA
  - CDSF COMPOSITE DATA PROCESSING OUTPUT (SEE TABLE. 4.1.2-1):
    - SUBSYSTEM DATA DISPLAYED IN RT IN THE FCC
    - EXPERIMENT DATA FOR REAL TIME USE BY CUSTOMERS
    - EXPERIMENT AND SUBSYSTEM LEVEL 0 DATA
    - ANCILLARY DATA FOR ENGINEERING SYSTEM COLLECTION, CUSTOMERS AND FCC
  - GROUND DATA RATES FOR CUSTOMERS ARE A FUNCTION OF:
    - EXPERIMENT OPERATIONAL DURATIONS
    - DELIVERY SCHEDULES

LOW RATE FORWARD LINK DATA AND MESSAGE DESCRIPTIONS

LISTED HERE ARE THE LOW RATE DATA DESCRIPTIONS FOR FORWARD LINK COMMUNICATIONS TO THE CDSF SPACECRAFT. OTHER MISSION AND ADMINISTRATIVE MESSAGES ONLY REQUIRE LOW DATA RATE CAPACITY.

LOW RATE FORWARD LINK DATA AND OTHER MESSAGE DESCRIPTIONS

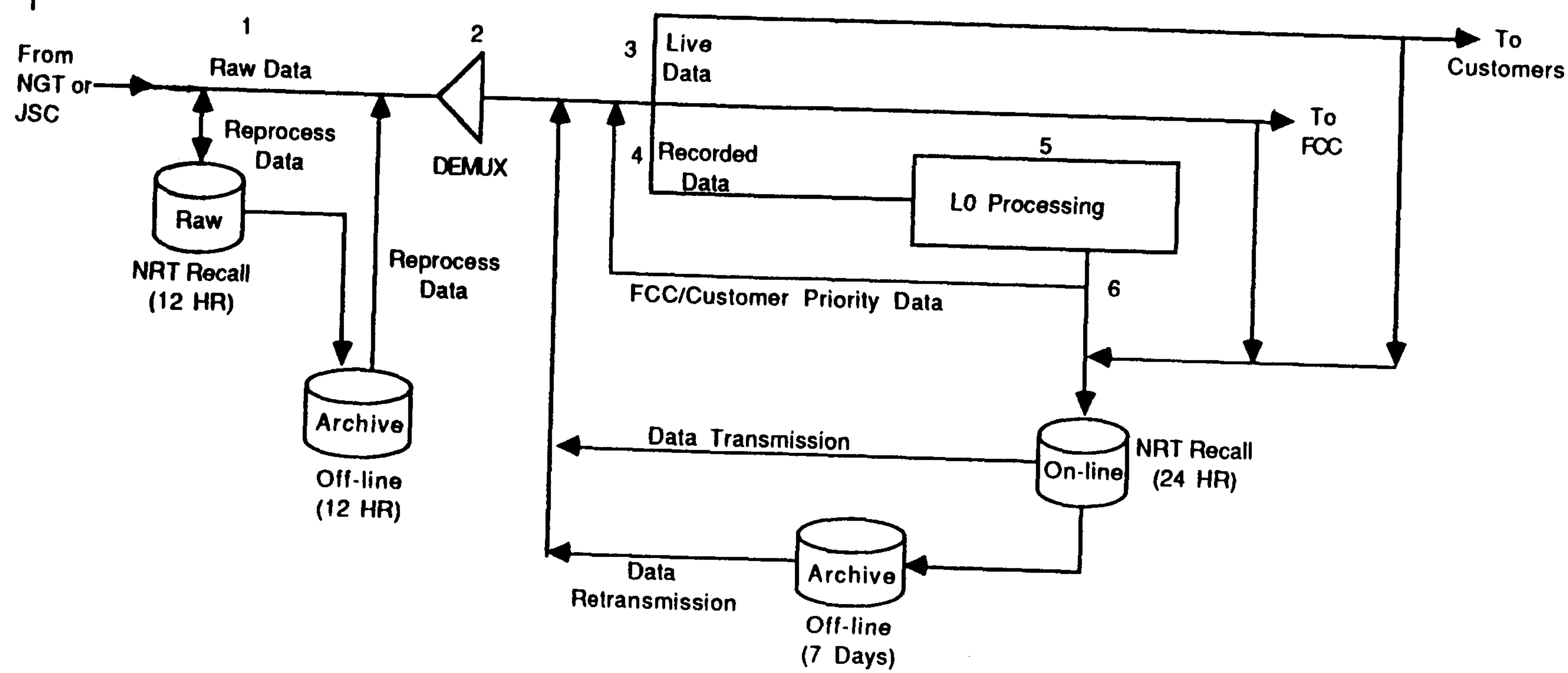
- FORWARD DATA
  - LOW RATE (2-20 KBPS) COMMAND WORDS AND PROCESSOR FILES
  - FILE STREAMS CONSISTING OF SUBSYSTEM AND OR EXPERIMENT CODED DATA WORDS
- OTHER MESSAGES (LOW RATE DATA - 10'S OF KBPS)
  - FLIGHT DYNAMICS DATA TO/FROM GSFC
  - PLANNING AND SCHEDULING MESSAGES TO/FROM CUSTOMERS, JSC, GSFC NCC

CDSF GROUND MDHS DATA FLOW DESCRIPTIONS

THE FOLLOWING FIVE DIAGRAMS ILLUSTRATE THE DATA PROCESSING FLOW AND NETWORK DATA PATHS FOR CDSF FORWARD AND RETURN DATA. THE CDSF FLIGHT CONTROL CENTER AND DATA PROCESSING FACILITY ARE ASSUMED LOCATED SOMEWHERE DIFFERENT THAN THE NASA FACILITIES SHOWN. FORWARD DATA IS ROUTED TO EITHER JSC OR GSFC FOR RELAY TO THE STS/CDSF OR THE FREE FLYER CDSF RESPECTIVELY. THE CDSF CONTRACTOR FLIGHT CONTROL CENTER RELAYS CUSTOMER FORWARD DATA, EITHER STORED OR IN REAL TIME. FORWARD DATA PATHS FROM CUSTOMERS TO THE CDSF CONTRACTOR UTILIZE PUBLIC SERVICE DATA PATHS. CDSF CONTRACTOR FORWARD DATA, CONSISTING OF CDSF SUBSYSTEM AND EXPERIMENT COMMANDS, ARE LINKED TO NASA VIA NASCOM IF POSSIBLE.

RETURN DATA WOULD UTILIZE NASCOM BETWEEN NASA INSTITUTIONS (JSC OR THE NASA GROUND TERMINAL) THE CDSF CONTRACTOR DATA PROCESSING FACILITY AND DEMULTIPLEXED OR PROCESSED IS SENT TO THE CUSTOMERS VIA PUBLIC SERVICE.

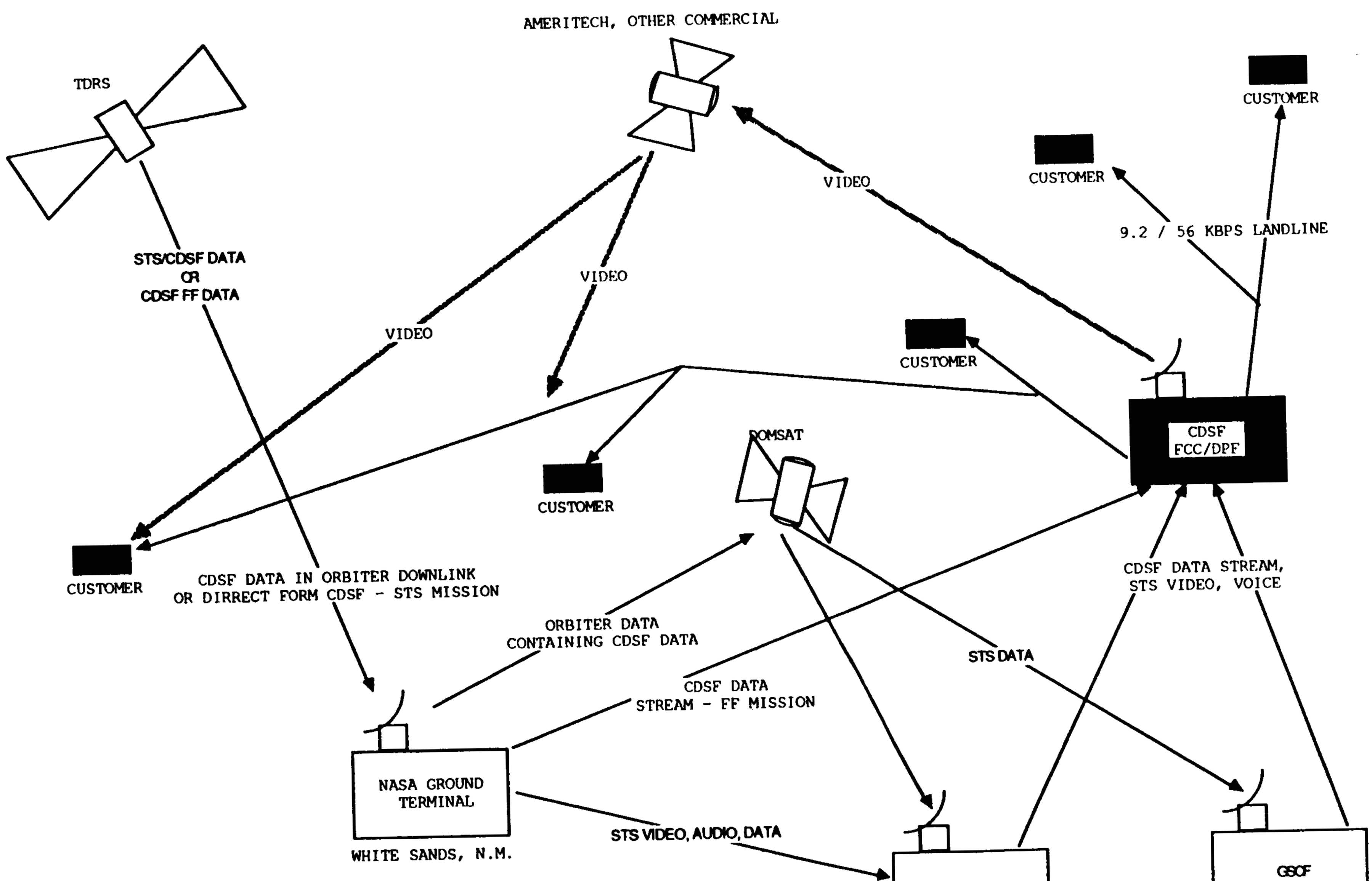
CDSF DATA FLOW



Data Flow:

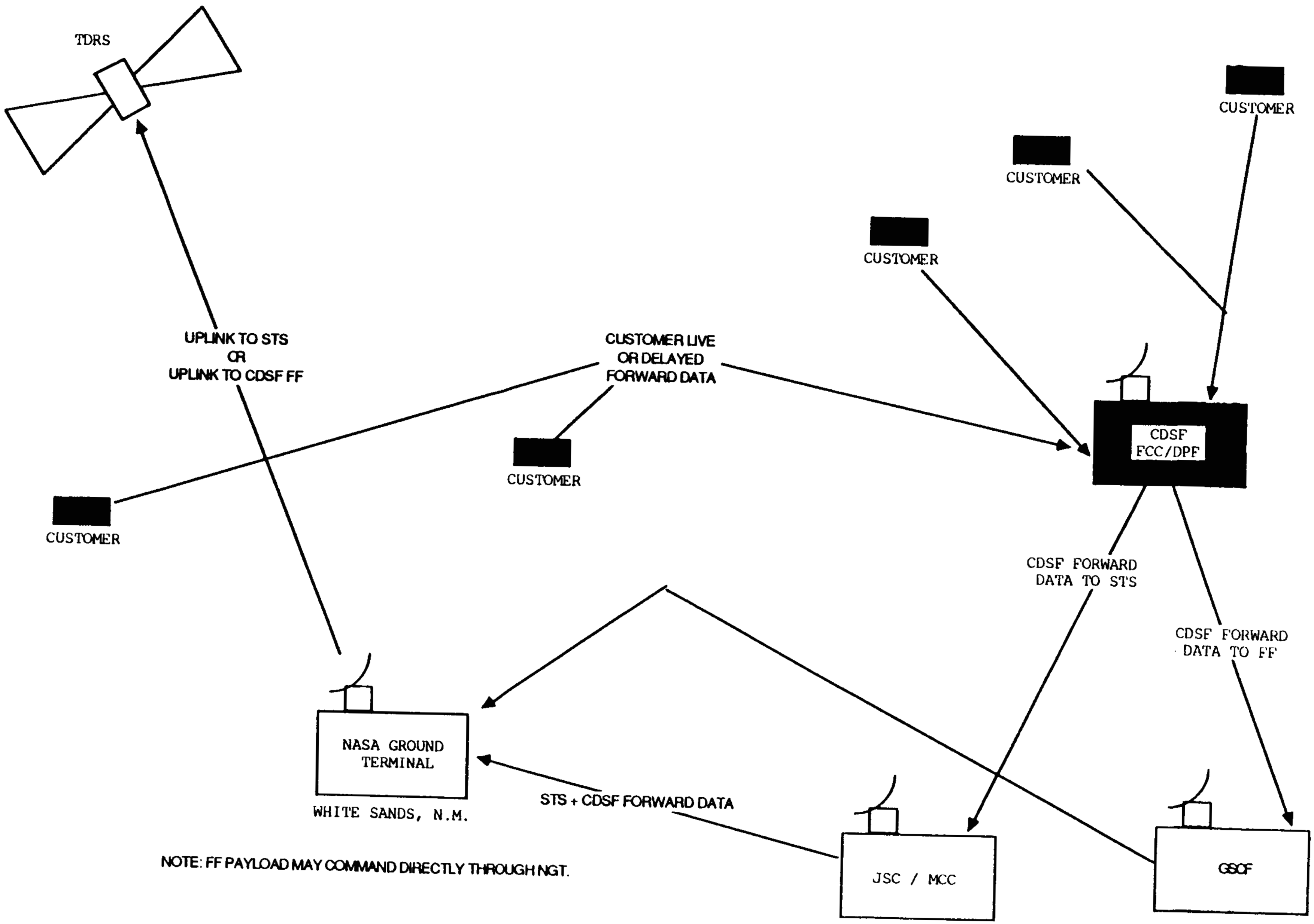
1. Raw data is received, and sent to the demultiplexer and to storage. The data is in a CDSF Composite data stream form.
2. At the demultiplexer, the data is separated into indivdual packets streams of Operational Live Data and Recorded Data. Operational Live Data Packets consist of FCC Live Data and Customer Live Data. Recorded Data is all other.
3. Customer Live Data is transmitted to the designated customers and to storage devices. FCC Live Data is transmitted to the FCC for real time analysis and display and to storage devices.
4. Recorded and Live data are sent to the Level 0 processor. Recorded data consists of experiment data and CDSF engineering data, some of which is Priority Data.
5. Level 0 processing consists of sorting and time ordering data, removal of redundant packets, and if recorded data is received in reverse order, the data is reversed to the proper order. Any priority playback data is sent to destination without being Level 0 processed.
6. After being processed, CDSF Engineering and Customer Data are sent to the customers, ESF, and to the storage devices.

CDSF RETURN DATA PATHS - STS AND FF MISSION



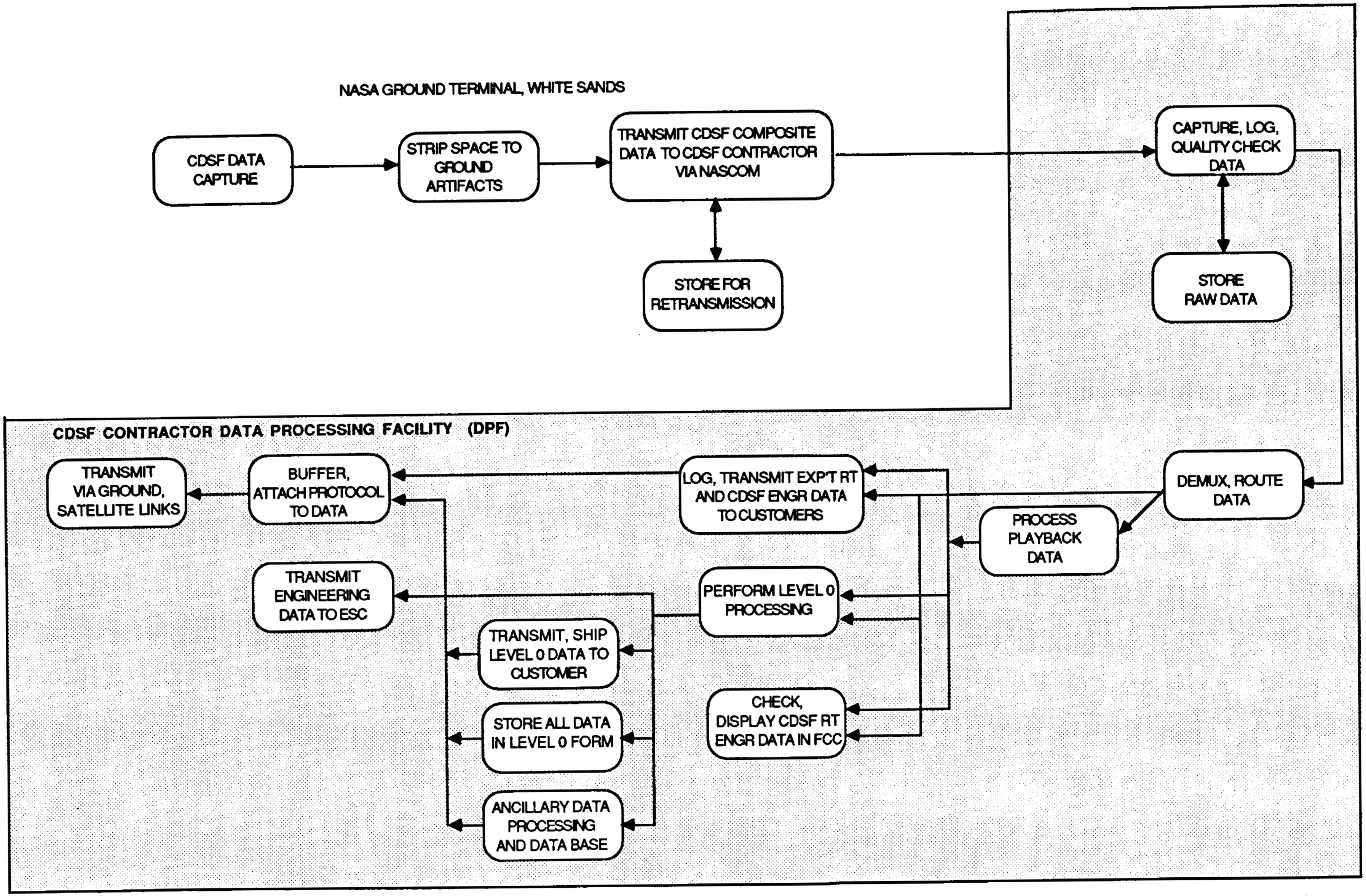
NOTE: STS DATA PATH TO JSC AND GSFC DEPENDS ON MISSION BW. DOMSAT LINK SHOWN IS PRESENTLY THE ONLY HIGH RATE PATH.

CDSF FORWARD DATA PATHS - STS AND FF MISSION

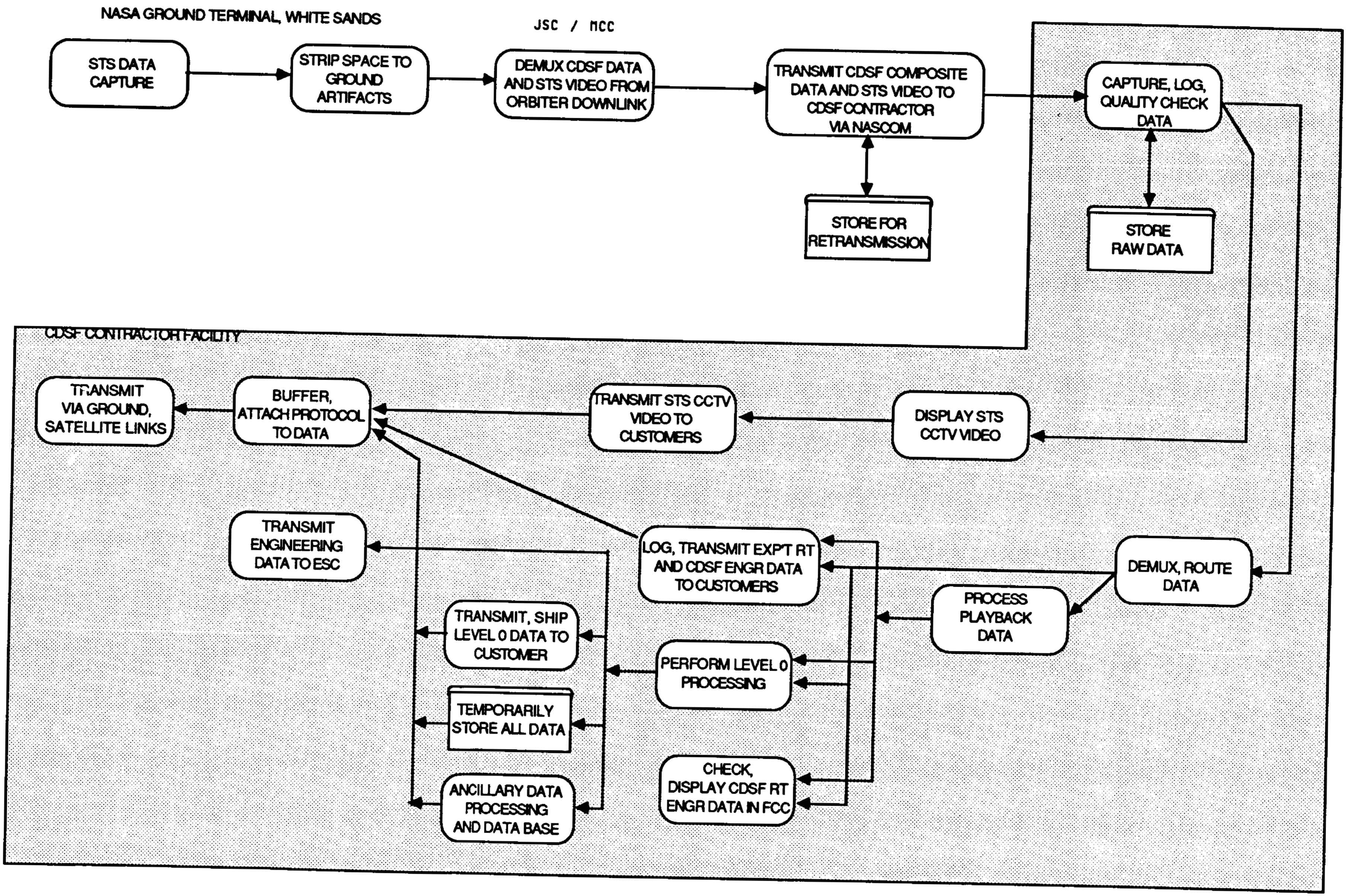


NOTE: FF PAYLOAD MAY COMMAND DIRECTLY THROUGH NGT.

CDSF RETURN DATA GROUND FLOW FOR FREE FLYER MISSION



CDSF RETURN DATA GROUND FLOW FOR STS MISSION



CDSF GROUND MDHS FACILITY LOCATION CONSIDERATIONS

FACILITY LOCATIONS ARE DISCUSSED TO BRIEFLY DESCRIBE ISSUES AND FACTORS TO BE CONSIDERED FOR SITE SELECTIONS. THE MAIN DRIVERS ARE EXISTING COMPANY FACILITIES, STS MISSION FREQUENCY, AND DATA COMMUNICATION DISTANCES. IF STS INTEGRATION OCCURS OFTEN THEN SOME SAVINGS ARE REALIZED BY COMBINING INTEGRATION AND MISSION OPS NEAR KSC, FLA. IF FREE FLYER MISSIONS ARE MORE THE RULE THEN THE OTHER TWO FACTORS PREVAIL, I.E. - EXISTING FACILITIES AND COMM DISTANCES.

CDSF GROUND MDHS FACILITY LOCATION CONSIDERATIONS

- FACILITY LOCATION ISSUES AND FACTORS:

1. LOCATION OF CDSF CONTRACTOR (CC) INTEGRATION & TEST SITE NEAR KSC:
   - ALLOWS SHORT TRANSPORT TO LAUNCH SITE FOR INTEGRATED CDSF (SHIPMENT OF AN INTEGRATED AND VERIFIED CDSF)
   - ACCESS TO MERRITT ISLAND GROUND STATION FOR PRELAUCH END TO END TESTS

2. LOCATE ALL CDSF FACILITIES AT KSC OR ELSEWHERE TO SHARE COMPUTING, MANPOWER AND COMMUNICATIONS RESOURCES.

3. LOCATE FACILITIES AT DIFFERENT EXISTING COMPANY GEOGRAPHICAL LOCATIONS TO SAVE LAND AND CONSTRUCTION COSTS.

4. DATA TRANSPORT DISTANCES MUST BE CONSIDERED BETWEEN:
   - GSFC AND CC DPF/FCC (DPF - DATA PROCESSING FACILITY)
   - JSC AND CC DPF/FCC (FCC - FLIGHT CONTROL COMPLEX)
   - WHITE SANDS AND CC DPF/FCC
   - DPF AND CUSTOMERS
   - DPF/FCC TO COMMERCIAL HUBS, SATELLITE GROUND STATIONS.

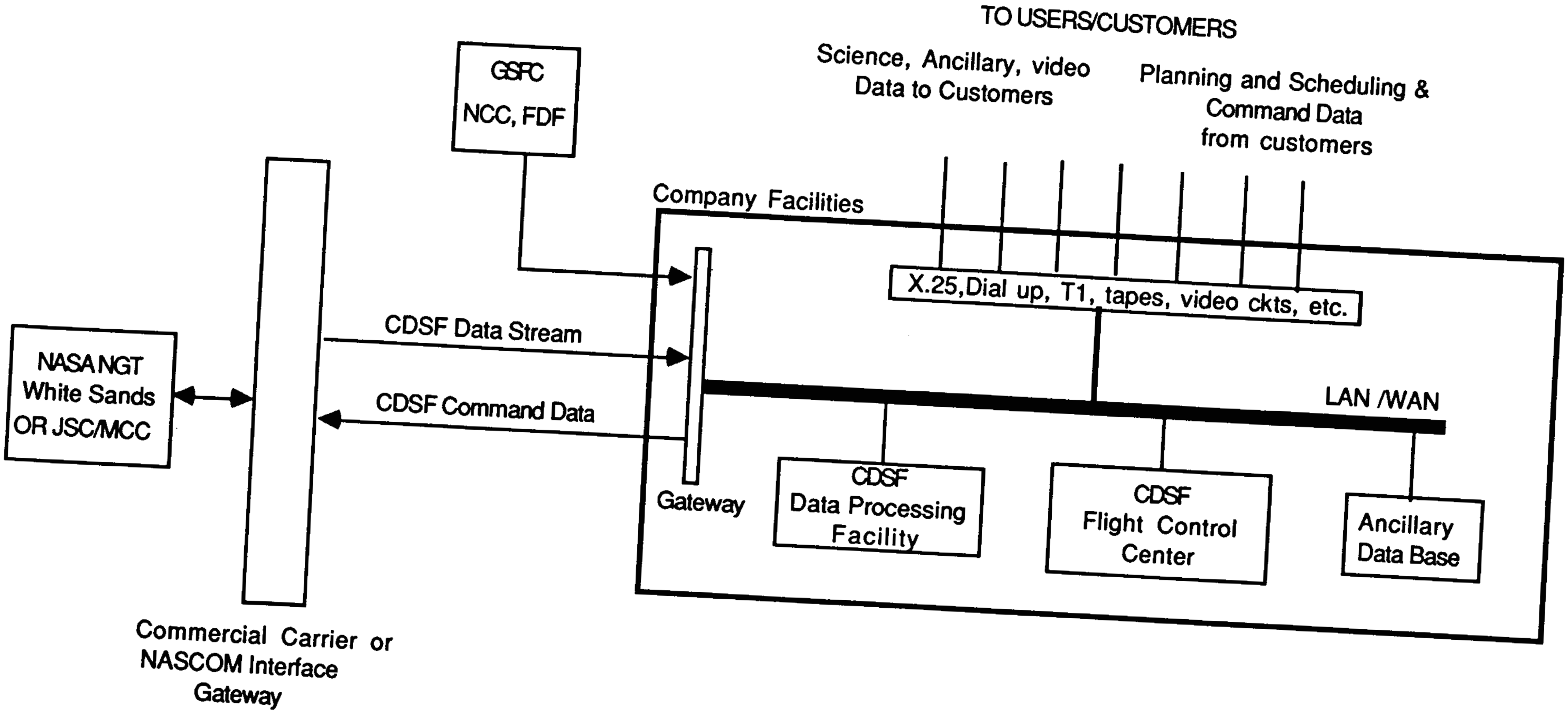
5. COLLOCATION OF ALL CDSF FACILITIES PROVIDES BETTER OPERATIONAL EFFICIENCY

GROUND MDHS CONFIGURATION FACILITY CONCEPT

THERE ARE ADVANTAGES AND DISADVANTAGES OF LEASE VERSUS PURCHASE DATA PROCESSING OPTIONS FOR CDSF. WHILE LEASING SERVICE FROM NASA IS ATTRACTIVE IN SEVERAL WAYS, IT IS PREFERABLE TO DO THE PROCESSING "IN HOUSE" WITH EITHER NEW OR EXISTING SYSTEMS, INDEPENDENT OF GOVERNMENT ACCESS AND OPERATIONAL REGULATIONS AND RESTRICTIONS.

A CONCEPT FOR THE ARCHITECTURE FOR MISSION DATA PROCESSING FACILITIES IS SHOWN. CDSF CONTRACTOR COMPANY FACILITIES, AS SHOWN, CONSIST OF A DATA PROCESSING FACILITY (DPF), A FLIGHT CONTROL CENTER, CENTRAL DATA BULK STORAGE AND RETRIEVAL CAPACITY AND NETWORK COMMUNICATION EQUIPMENT/GATEWAYS TO (1)COMMERCIAL CARRIER OR NASCOM FOR SPACECRAFT CONTROL AND (2) EXPERIMENT CUSTOMER INFORMATION ACCESS. THESE FACILITIES PROVIDE LEVEL 0 PROCESSING, ANCILLARY DATA PROCESSING AND STORAGE, REAL TIME DATA HANDLING AND ANALYSIS (SPLIT FUNCTION WITH THE FCC AND ESF) AS WELL AS VIDEO AND VOICE ROUTING AND TELECOMMUNICATIONS PROTOCOL HARDWARE. THE DPF INCLUDES INPUT/OUTPUT PROCESSORS TO SOLVE THE I/O BOTTLENECKS TYPICAL OF SUCH APPLICATIONS, FAST AND SLOW ACCESS STORAGE, AND A VARIETY OF COMMUNICATION INTERFACES. ALL HARDWARE IS COMMERCIAL OFF THE SHELF.

CDSF Operations Concept - Data Handling



GROUND MDHS DATA PROCESSING AND FLIGHT CONTROL FACILITY CONCEPT

THE NEXT FOUR PAGES DESCRIBE THE CONCEPTS FOR THE CDSF GROUND MDHS DATA PROCESSING FACILITY (DPF) AND FLIGHT CONTROL CENTER (FCC). THE FIRST TWO FOLLOWING PAGES DETAIL THE CDSF PROCESSING AND STORAGE ESTIMATES BASED ON THE CUMULATIVE ANALYSIS PERFORMED UP TO THIS POINT. THE ASSUMPTIONS AND MODELS USED ARE SUMMARIZED. THESE NUMBERS ARE INTENDED TO BE WORST CASE, BASED ON AN STS MISSION WHICH WOULD HAVE THE MOST INTENSIVE MDHS REQUIREMENTS. (WHILE IT'S TRUE THAT A FF MISSION IS NOT CONSTRAINED TO THE STS 48 MBPS KU SIGNAL PROCESSOR INTERFACE, IT IS UNLIKELY THAT CDSF MISSIONS FOR THE EARLY TO MID 1990'S WOULD EVER REQUIRE HIGHER DATA RATES THAN THE STS PROFILE OF 45 MBPS BANDWIDTH MAXIMUM.)

THE FOLLOWING THIRD AND FOURTH PAGES PROVIDE FUNCTION DIAGRAMS AND DESCRIPTIONS FOR THE CDSF CONTRACTOR OWNED AND OPERATED DATA PROCESSING FACILITY AND THE FLIGHT CONTROL CENTER.

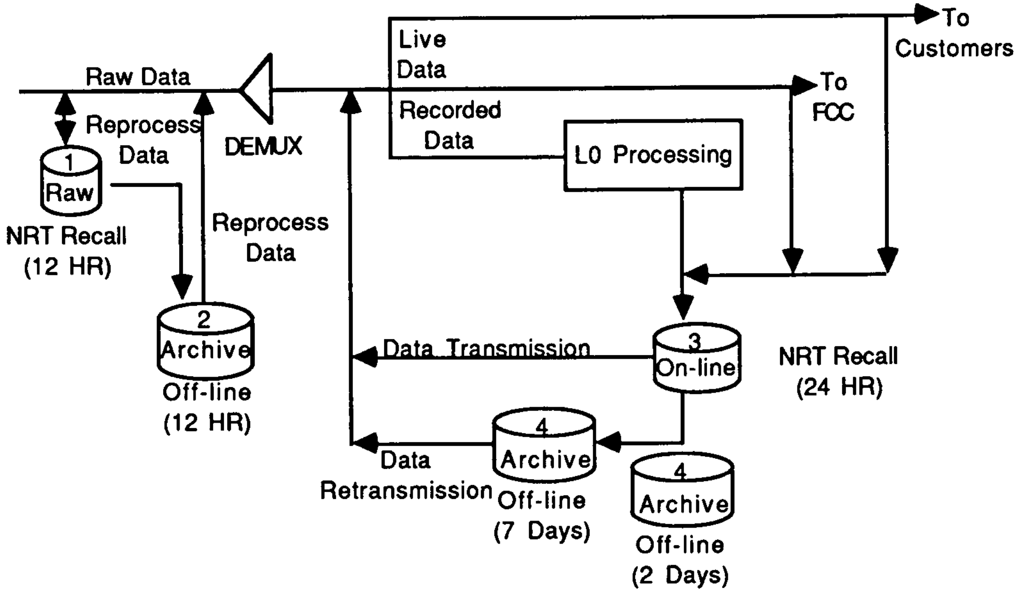
GROUND MDHS ESTIMATES FOR DATA PROCESSING AND STORAGE

- PROCESSING ESTIMATES:
  1. DAILY TOTAL AVERAGE CDSF DATA = 1.41 TB
  2. DPF AVERAGE DAILY THROUGHPUT RATE = 16 MBPS + MARGIN (20%) + REPROCESSING REQUESTS = 22.4 MBPS.
  3. DAILY TOTAL AVERAGE LEVEL O PROCESSED DATA = 1.41 TB + 20% REPROCESSING = 1.69 TB.
  4. DAILY CDSF LIVE DOWNLINK DATA = 720 GB
  5. DAILY CDSF PLAYBACK DATA = 693.6 GB
  6. DAILY FCC LIVE DATA (SUBSYSTEM DATA)= 1.728 GB
  7. DATA DELIVERED TO CUSTOMERS
     - IN 24 HOURS (ASSUME 90% OF ALL EXPERIMENT DATA) = 1.13 TB
     - IN 7 DAYS = 286.2 GB
     - TOTAL DATA SENT TO CUSTOMER IS THE DAILY VOLUMES GIVEN IN SECTION 4.1 TABLE 4.1.2-1
  8. DAILY REAL TIME DATA TO ALL CUSTOMERS = 155.6 MB
  9. DAILY ANCILLARY DATA PROCESSING = 1.18 GB

● GROUND MDHS STORAGE ESTIMATES (SEE FIGURE 4.2.4-5)

- ASSUMPTIONS:
  1. ALL RAW DATA IS STORED FOR 12 HOURS TO COVER DPF PROCESSING ANOMALIES
  2. LEVEL O PROCESSED DATA IS STORED OFFLINE FOR UP TO 7 DAYS FOR LOW RATE CUSTOMER DATA AND 12 HOURS FOR HIGH RATE CUSTOMER DATA

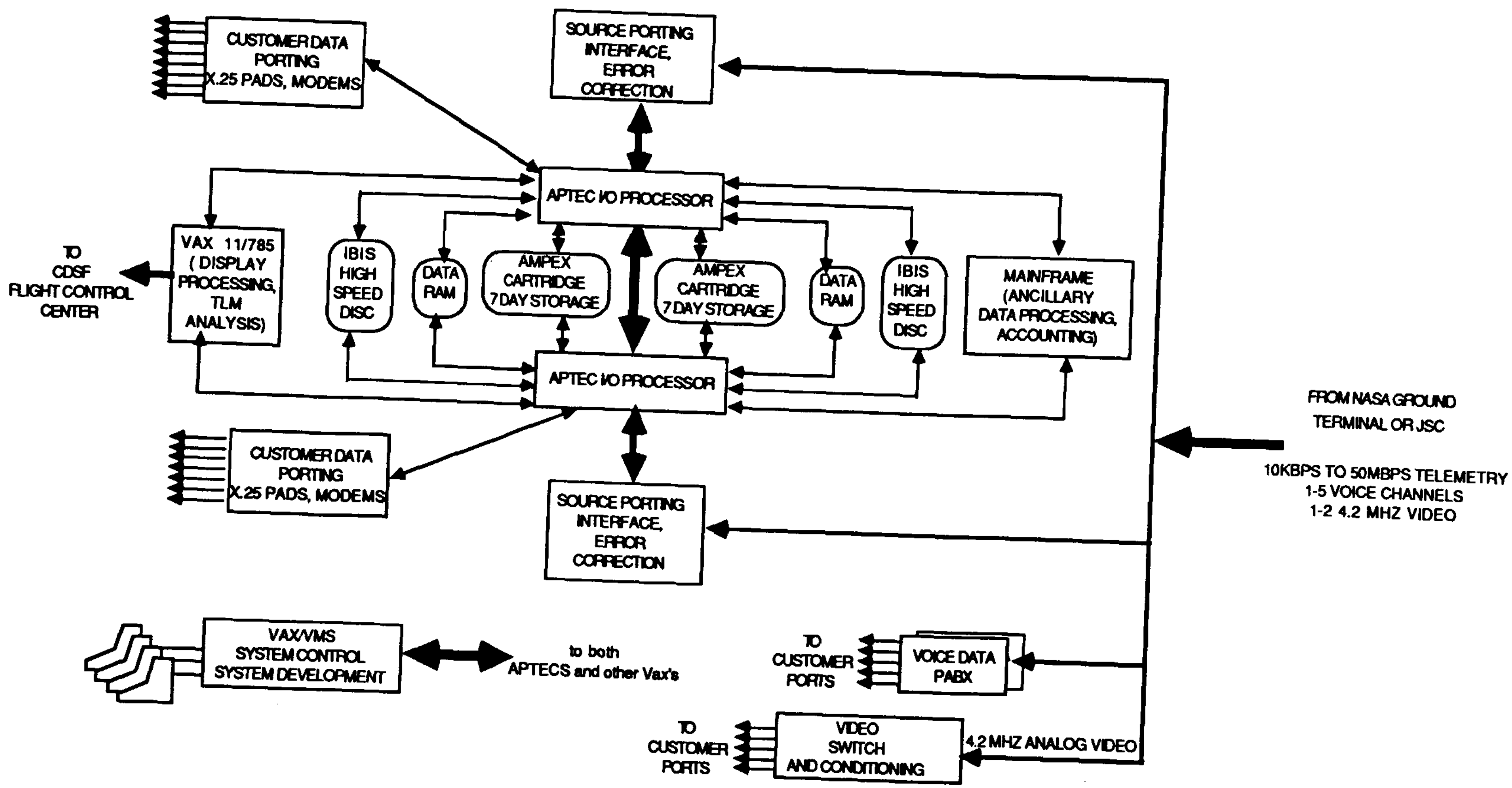
GROUND MDHS DATA STORAGE



DATA TYPE	GBYTES /DAY	CAP REQ (DAYS)	MAX VOL (GBYTES)
Short Term			
Non-Processed Input (Raw Data)	187.500	1	187.500
L0 DATA			
Recorded Exp't Data	86.500	2	173.140
Live Exp't Data	92.150	2	184.300
Live Eng. Data	.090	2	.180
Recorded Eng. Data	.126	2	.252
TOTAL			545.372
Long Term			
L0 Data	178.720	7	1251.040
All Eng Data	.216	7	1.512
Non-Processed Input	187.500	1	187.500
TOTAL			1440.052
Permanent Applications, History Tech Ref., etc.			500

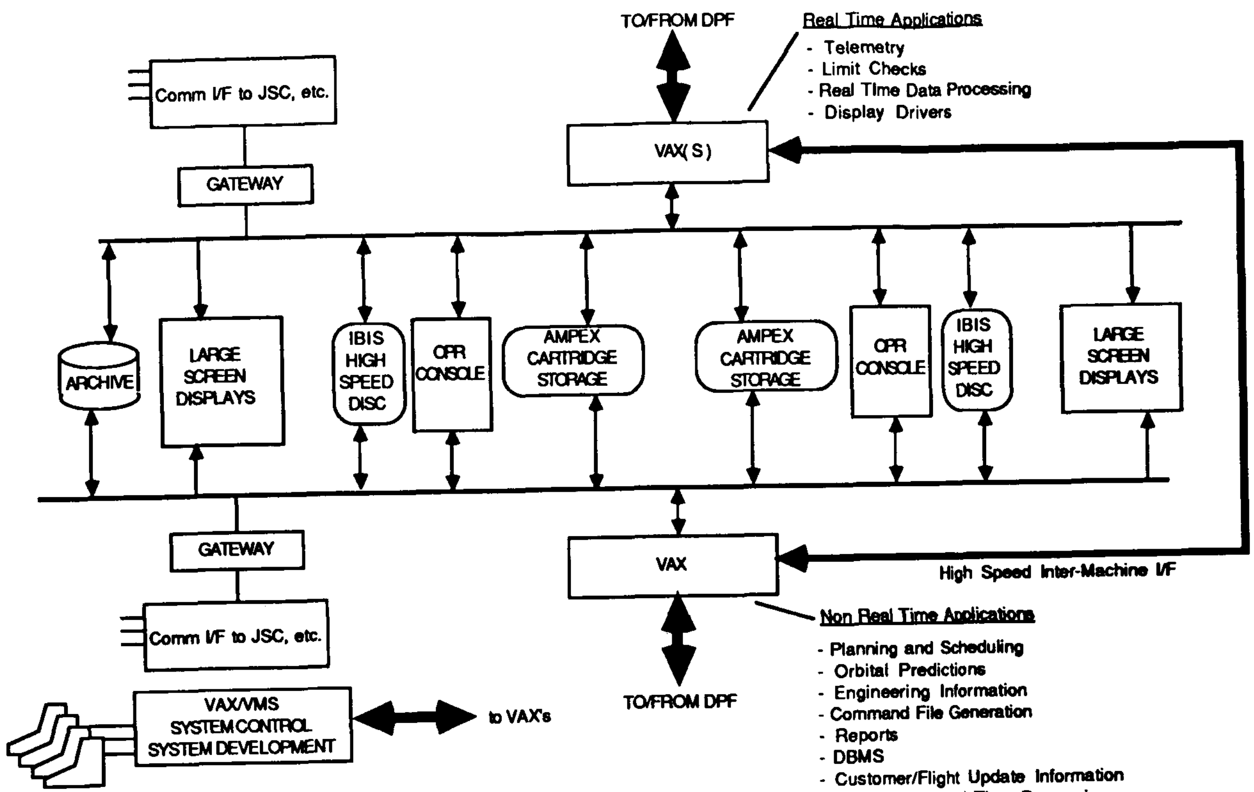
ASSUMPTIONS
- NASA Ground Source of CDSF data has storage and retransmission capability for 6-12 hours.
- Short Term Storage is required for all Raw data input to DPF, On-line Level 0 Data for customer access, and all Live data for NRT recall.
  - -- Raw data will be retained on-line for a period of 12 hours with the capacity for 24 hours.
  - -- Level 0 data and all Live data will be retained on-line for 24 hours with the capacilty for 48 hours.
- Long Term Storage is required for all Level 0 Data for customer access.
  - -- Level 0 Data will be retained off-line for a period of up to 7 days.
- Ancillary engineering data will be stored for 1 year.

CDSF GROUND MDHS DATA PROCESSING FACILITY



Features:
1. High speed I/O processors for data movement between application computers and periferals.
2. Versatile memory management for both high speed data manipulation and long term storage.
3. VAX/VMS interfaces for applications - accounting, display drivers, development, recorder playback processing, ancillary data processing, etc.
4. I/O to customers, flight control center, simulators, etc.
5. Accepts range of CDSF data and processes and routes video, audio.
6. Fully redundant strings.

CDSF GROUND MDHS FLIGHT CONTROL CENTER



Features:

1. High speed LAN for data movement between application computers and periferals.
2. Versatile memory management for both high speed data manipulation and storage.
3. VAX/VMS interfaces for applications - display drivers, development, consoles, MMI, etc.
4. I/O to DPF and JSC.
5. Accepts range of CDSF data, processes data for display on large screen or consoles
6. Fully redundant strings.
7. Distributed Processing facilitates load sharing during high processing periods.
8. Shared databases maximize data access and minimizes data storage requirements.
9. Access to long term storage provides opr access to trends and other historic data files.
10. VAX/VMS high processing rates provide rapid display and access to data.
11. VAX/VMS system control provides for maximum utilization of resources and rapid detection of network troubles.
12. High Speed Intermachine bus provides for machine speed data sharing and fault recovery.
13. Hot stand-by for real time processing.
14. On-Line archives of engineering data, historical records, consumables, etc.

ESTIMATES AND CONCEPTS FOR CDSF CONTRACTOR OWNED GROUND FACILITIES

THE NEXT 6 PAGES DESCRIBE AND ILLUSTRATE THE FUNCTIONS AND CONCEPTS FOR MAJOR CDSF CONTRACTOR OWNED FACILITIES REQUIRED FOR SUPPORT OF COMPLETE MISSION OPERATION AND DATA PROCESSING FUNCTIONS. FIVE FACILITIES ARE ESTIMATED TO BE REQUIRED, EITHER SEPARATE OR COMBINED IN SOME FASHION, TO FULLY SUPPORT CDSF MISSIONS. APPROXIMATELY 85 OPERATIONAL PERSONNEL ARE ESTIMATED TO BE REQUIRED, NOT INCLUDING MANAGEMENT AND ADMINISTRATION, TO STAFF THE FACILITIES FOR THE OPERATIONAL PHASE OF THE MISSION OPERATIONS.

CDSF CONTRACTOR OWNED GROUND FACILITIES

- CDSF CONTRACTOR WOULD REQUIRE FIVE MAJOR FACILITIES
  1. FLIGHT CONTROL CENTER (FCC)
  2. DATA PROCESSING FACILITY (DPF)
  3. INTEGRATION AND TEST FACILITY (I&T)
  4. SOFTWARE DEVELOPMENT FACILITY
  5. ENGINEERING SUPPORT FACILITY
- LEVEL 0 PRODUCTION DATA PROCESSING COULD BE DONE WHEREVER COMMUNICATIONS COSTS, FACILITY AND COMPUTATIONAL RESOURCES ALREADY AVAILABLE
- I&T SITE NEAR KSC BEST IF CDSF/ STS INTEGRATION OCCURS OFTEN.
- FLIGHT CONTROL CENTER CAN BE LOCATED ANYWHERE BECAUSE THE MISSION OPERATIONS PREPARATIONS (SOFTWARE LOADS, TESTS AND TRAINING, ETC.) OCCUR IN PARALLEL WITH I&T SO RESOURCES COULD NOT BE SHARED.
- SOFTWARE DEVELOPMENT FACILITY SHOULD BE COMBINED WITH FCC OR DPF TO SHARE RESOURCES AND EXPERTISE.
- ENGINEERING SUPPORT FACILITY SHOULD BE LOCATED AT I&T SITE OR FCC DEPENDING ON THE LENGTH OF GROUND INTEGRATION PERIODS AND FREE FLYER MISSION OPERATIONS NEEDS.

CDSF FACILITIES OVERVIEW

FLIGHT CONTROL CENTER

- REAL TIME DATA MONITOR
- COMMANDING
- MCC INTERFACE FOR STS MISSIONS
- PARTICIPATE IN SIMS AND TRAINING
- PRODUCE MISISON TIMELINES
- NCC INTERFACE FOR TDRSS SCHEDULING
- CDSF LO FI SIMULATOR
- DATA LINK TESTS (TO CUSTOMERS, NASCOM, JSC MCC, DOMESTIC CARRIERS, ETC.)

SOFTWARE DEVELOPMENT FACILITY

- FLIGHT SOFTWARE
- DATA PROCESSING SOFTWARE
- ACCOUNTING, MANAGEMENT PROGRAMS
- PLANNING AND SCHEDULING PROGRAMS
- CUSTOMER APPLICATIONS FOR CDSF INTERFACE
- TEST PROGRAMS

DATA PROCESSING FACILITY

- REAL TIME ENGINEERING FOR FCC
- REAL TIME DATA FOR CUSTOMERS
- LEVEL 0 PROCESSING FOR CUSTOMER DATA
- RECORDER PLAYBACK PROCESSING
- ANCILLARY DATA FOR CC AND CUSTOMERS
- VIDEO ROUTEING, RECORDING
- VOICE ROUTEING AND RECORDING
- DATA STORAGE FOR RETRANSMISSION
- ANCILLARY DATA ARCHIVE AND CUSTOMER INTERFACE
- ACCOUNTING AND ENGINEERING DATA BASE

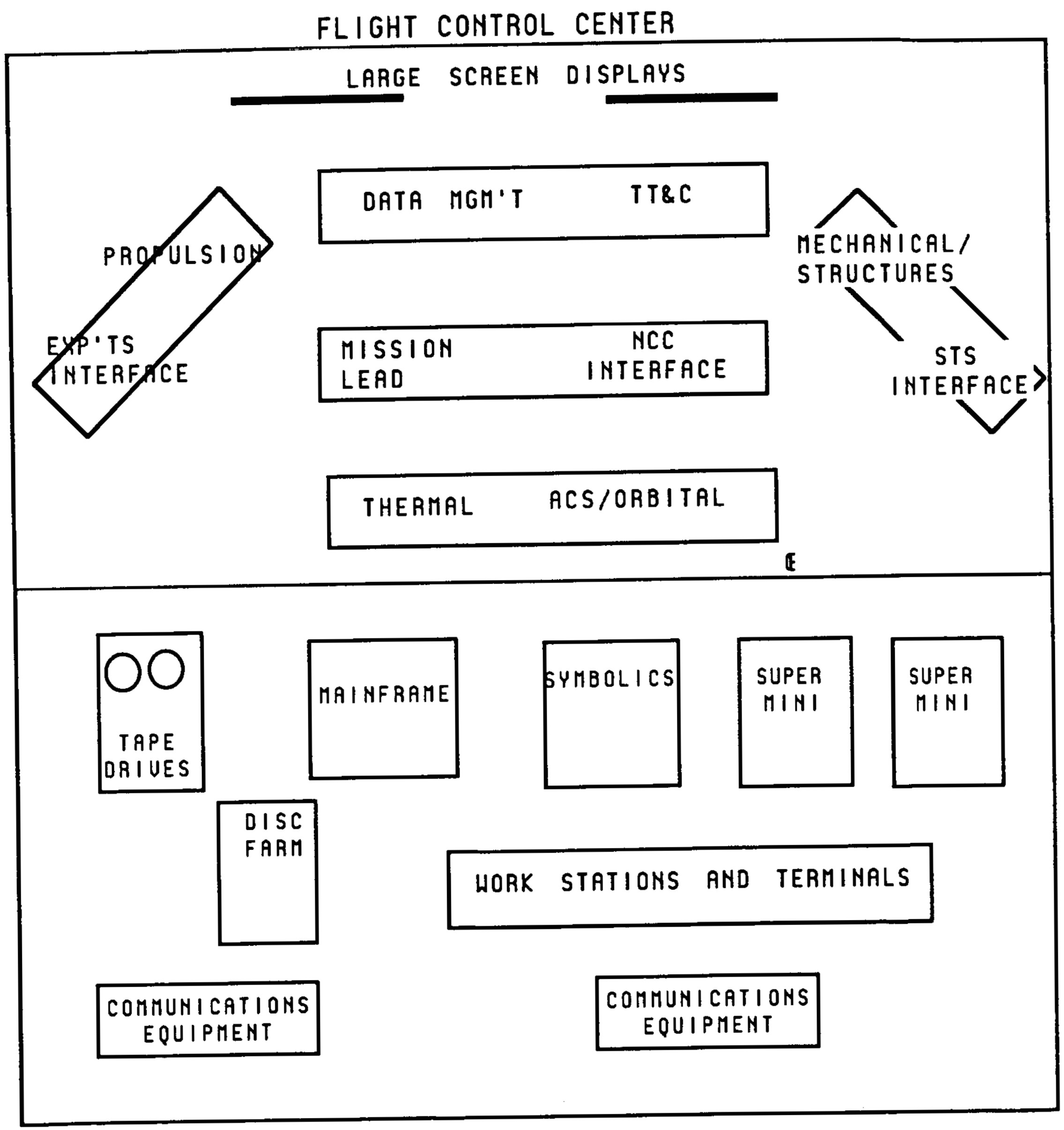
ENGINEERING SUPPORT FACILITY

- ENGINEERING AND PERFORMANCE ANALYSIS OF CDSF SYSTEMS, DATA QUALITYE, FLIGHT DYNAMICS/ GSFC FDF INTERFACE
- CONSUMABLE PREDICTS
- STS TECHNICAL INTERFACES
- CUSTOMER TECHNICAL INTERFACE
- GROUND DATA TRANSPORT MANAGEMENT

INTEGRATION AND TEST FACILITY

- PREFLIGHT EXPERIMENT/RACK INTEGRATION
- CDSF BUILDUP AND TEST
- RACK/EXPERIMENT/CDSF INTEGRATION
- CDSF MOCKUP (CREW TRAINING, CUSTOMER PLANNING)

CDSF FACILITIES OVERVIEW



OTHER EQUIPMENT

1. LARGE SCREEN VIDEO DISPLAYS
2. INTERCOM
3. LANS, GATEWAYS

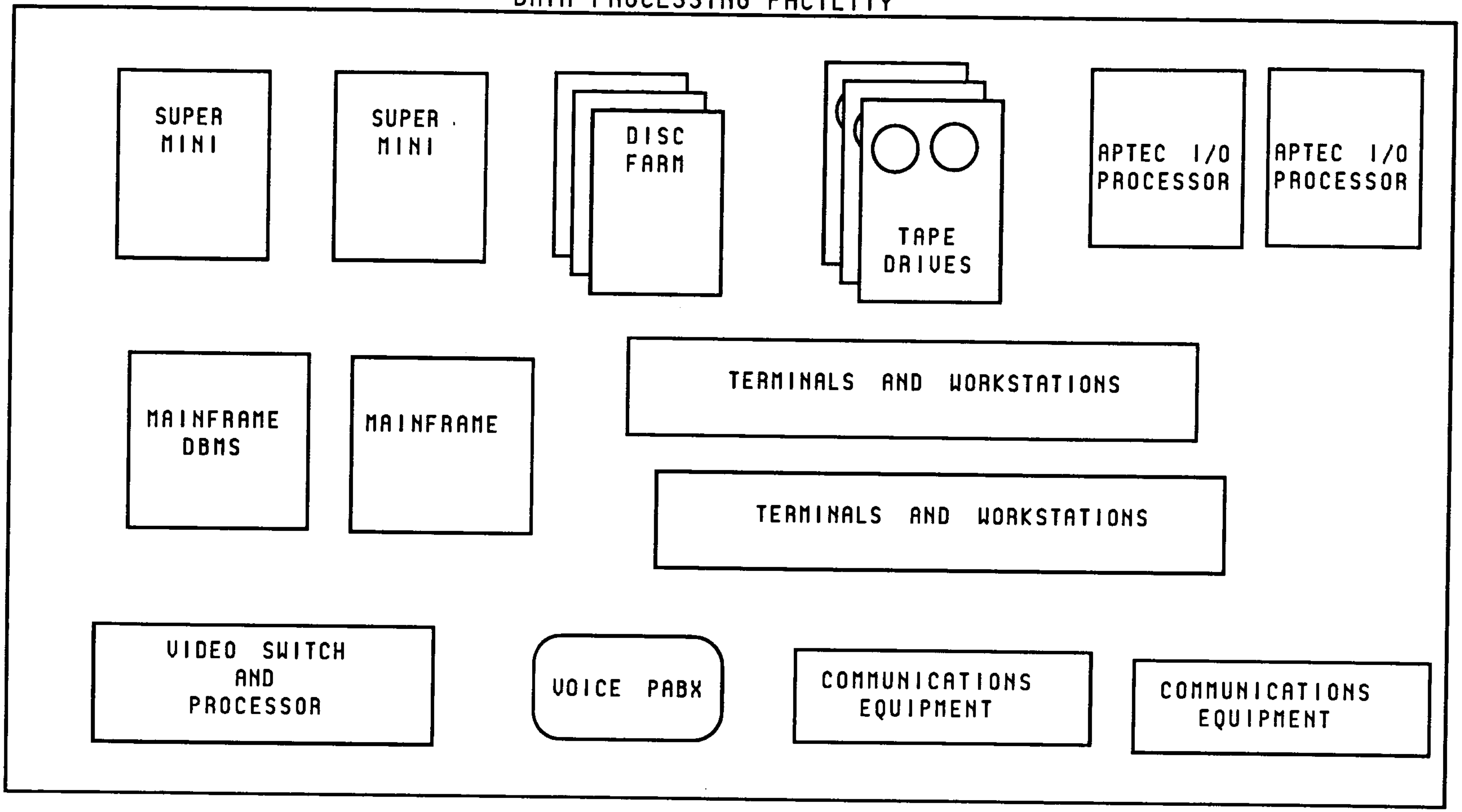
PERSONNEL ESTIMATES

1. REAL TIME OPERATIONS
   12 (4 PER SHIFT)
2. PLANNING AND SCHEDULING
   4 ENGINEERS
3. NCC INTERFACE AND LINK PLANNING
   3 ENGINEERS
4. COMPUTER OPERATIONS/MAINTENANCE
   5 PEOPLE
5. SOFTWARE SUPPORT - 2 PEOPLE

TOTAL= 26

CDSF FACILITIES - DATA PROCESSING FACILITY

DATA PROCESSING FACILITY

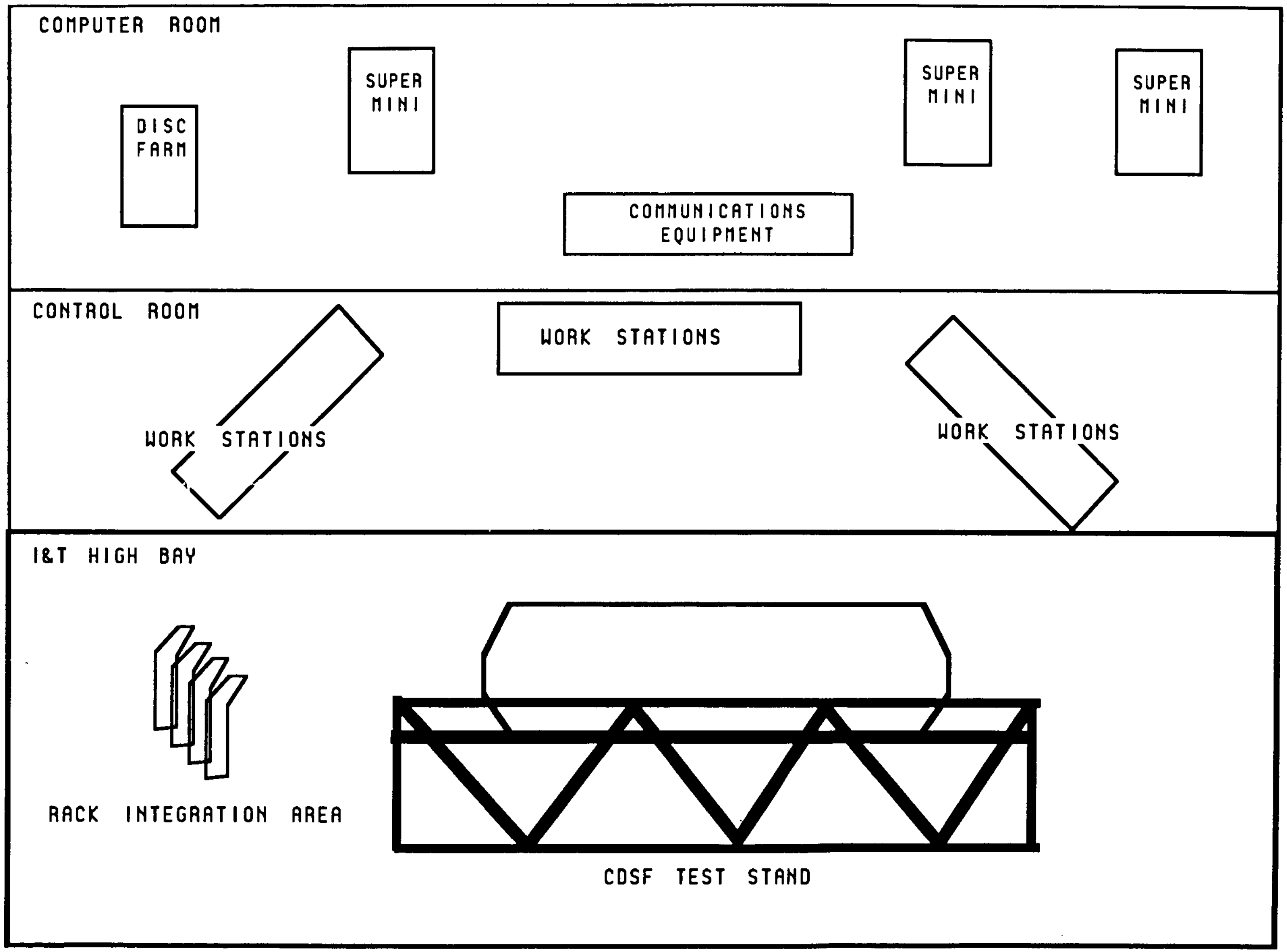


PERSONNEL ESTIMATES

1. COMPUTER OPERATIONS AND MAINTENANCE -9 (3 PER SHIFT)
2. COMMUNICATIONS - 3 (1 PER SHIFT)
3. VOICE AND VIDEO HANDLERS - 2
4. SOFTWARE SUPPORT - 4
5. MANAGEMENT - 2

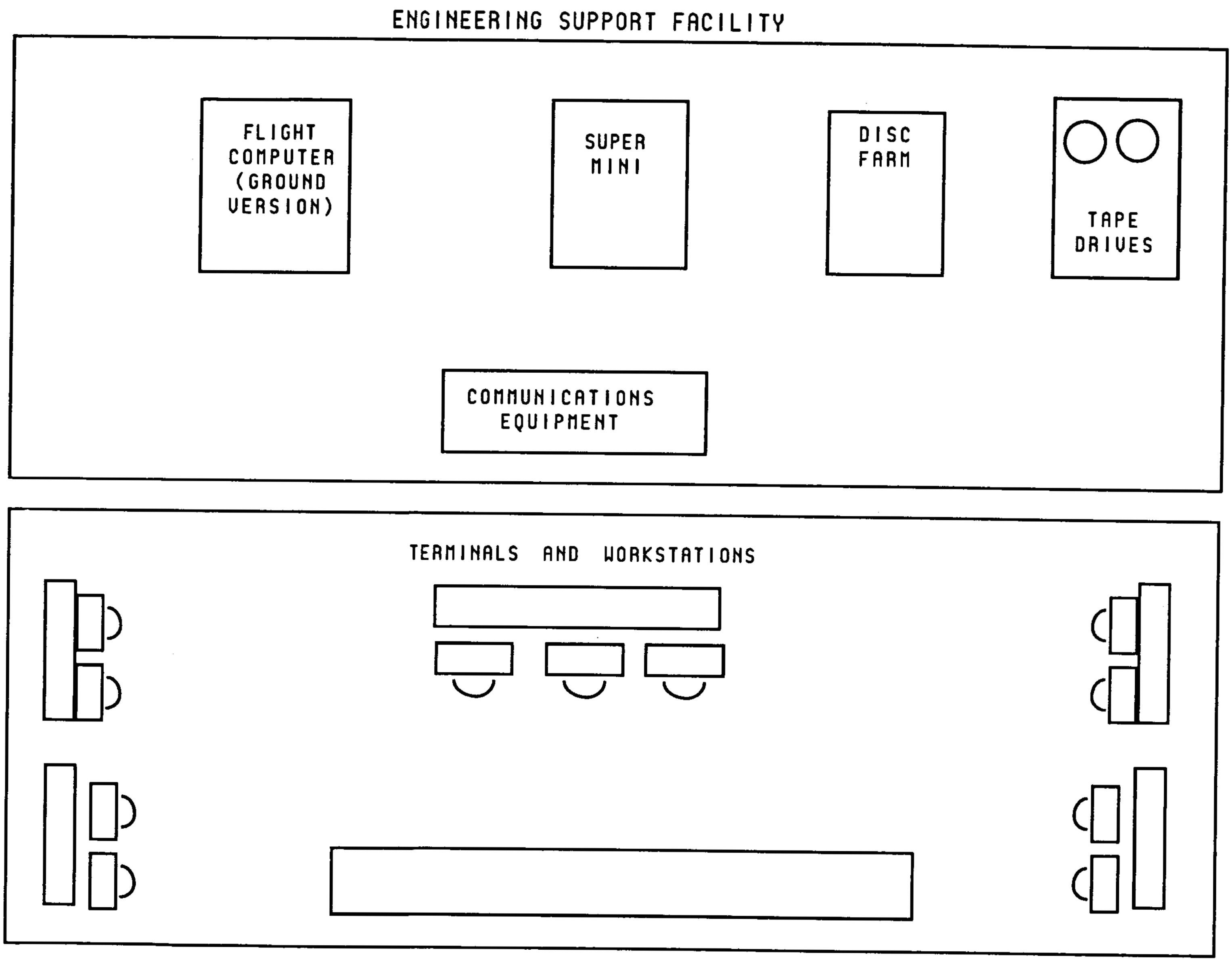
TOTAL = 20

INTEGRATION AND TEST FACILITY



PERSONNEL
1. TECHNICIANS - 10
2. TEST ENGINEERS - 12
3. COMPUTER OPS - 4
4. OTHER - 5

CDSF FACILITIES OVERVIEW



PERSONNEL
1. COMPUTER OPERATORS - 2
2. SOFTWARE ENGINNERS - 6

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10.0 SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND OBSERVATIONS

SUMMARY CONCLUSIONS, RECOMMENDATIONS AND OBSERVATIONS

The purpose of this NASA in-house study was to provide a reference concept definition for two CDSF configurations. It was not the intention of these studies to establish NASA microgravity experimentation program needs nor to establish or define user needs. It was primarily a space systems definition and sizing study. In the course of performing such studies, observations are made and opinions formed as the analysis, data interpretation and systems trades are made. The intent of this section is to document these thoughts for consideration in NASA CDSF evaluation activity for the purpose of making decisions regarding Agency position or use of such an orbital space facility. These comments are offered with respect to the two configurations defined. The first concept definition is responsive to the NASA March 28, 1988 draft RFP. The second concept is a reduced capability based on minimum needs as derived from review of NASA space science and commercial program microgravity experiment program definitions.

The size and capability of Concept 1 is optimized to that which can be accommodated with a single Space Shuttle Orbiter initial deployment launch. The performance for the initial launch is further constrained by the operational capability of the OV-102 (Columbia) with regard to mass to orbit capability. It is concluded that a CDSF concept which meets the RFP specifications is viable. However, the requirement for articulating solar arrays to constantly track the sun while attached to the Orbiter can not be substantiated. Experiment power levels and conceptual mission operational scenarios do not appear to demand it. If the need does materialize for such a mission definition utilization, adequate power can be provided using Shuttle Orbiter power augmentation kits under consideration for development for the Extended Duration Orbiter (EDO) capability.

The Concept 2 reduced capability definition appears to offer viable 5 year mission utilization scenario considerations that match, with respect to experiment microgravity environment accommodation, volume and power, the defined concept and resource capability . The combination resupply and docking module concept permits Shuttle tended missions and Free Flier missions to be planned and performed independently of each other. The three main elements that comprise the Concept 2 definition, the resupply/docking module, the spacecraft bus with (or without) a power augmentation module, and the experiment module, each offer unique commercial venture opportunities independently. Concept 2 could provide consideration of lower cost lease options than the single pressurized Concept 1 definition by the use of unpressurized experiment accommodation options.

SUMMARY CONCLUSIONS, RECOMMENDATIONS, AND OBSERVATIONS

MISSION SCENARIOS

The mission scenarios were derived solely to establish sizing parameters for CDSF configuration definition purposes. They are mission models conceived for the purpose of performing trade studies between experiment processing run times, energy generation and storage level, acceleration limit accommodation, and launch vehicle payload lift capability. The key parameters considered for mission set definition were experiment run time and time sequenced experiment power demands for representative experiment sets. The mission sets provided mission level requirement definitions for both Shuttle tended missions and free flyer missions. The derived mission scenarios also provided requirements for interface definitions for the NSTS vehicle and its mission control system and also definitions for a CDSF free flyer mission control and data handling system. The level to which telescience should be considered for CDSF operations was also derived from these mission scenarios.

MICROGRAVITY EXPERIMENT SENSED ACCELERATION LEVELS

CDSF configuration definitions focus on orbital flight mode passive stability orientations for both Shuttle tended and free flyer missions to accommodate NASA documented sensed acceleration magnitude and vector direction limits for low microgravity experimentation requirements. Gravity gradient stabilization utilizing extended boom tip masses and feathered solar array geometry are the key techniques for obtaining quasi–steady state conditions without the need for active reaction torque control in either the STS/CDSF mated mode for periods up to 12 hours or in the free flyer mode for periods of 30 days. Concepts derived for maintaining CDSF center of mass alignment with respect to the orbital flight path must be implemented for experimentation consistency between shuttle tended and free flyer flight mode.

System dynamic disturbances in the form of crew motion can be operationally planned commensurate with passively stabilized flight control to yield undisturbed experiment run times for periods of several hours rather than several minutes as currently provided. Background noise disturbance as measured from past Shuttle flight experience is seen to be just at the borderline limit of acceptability for the frequency spectrum defined. This area needs more assessment with regard to acceptable limits for experimentation and on board disturbance measurements.

SUMMARY CONCLUSIONS, RECOMMENDATIONS, AND OBSERVATIONS

POWER GENERATION

CDSF power generation requirements are driven by the combination of the energy need descriptions for the CDSF candidate experiments and the defined mission scenarios that yield the highest experiment capture level and reflight opportunity during the proposed 5 year lease period. In the case of Concept 1 the Shuttle Orbiter OV-102 up mass performance was also a constraining factor.

7 KW average power as defined for Concept 1 appears to be a reasonable conceptual level to implement as a non-articulating feathered solar array power generation design. This approach is key to enabling an acceptable quasi-steady state microgravity environment.

For Concept 2, a 3 to 4 KW capability will satisfy the mission scenarios defined as models for this study.

DEPLOYMENT, RENDEZVOUS, REVISIT AND DISPOSAL/RETRIEVAL MISSIONS

The requirement to initially deploy at a specified altitude of 160 nautical miles creates undesirable sizing constraints when follow on revisit missions and a 3 year contingency altitude are considered. Rendezvous and reboost assessments performed indicate that a 600 pound fuel penalty results from implementation of the requirement to maintain a 0.2 degree per day rate for the right ascension of the ascending node (RAAN) maneuver capability between revisit missions.

Analysis performed shows that retrieval of the CDSF intact is the safest and most cost effective approach for disposal after completion of its useful life. The cost and weight penalty of utilizing a large enough on-orbit propulsion system to provide a predictable dispersion impact footprint can be offset by retrieving the CDSF with a shared (non-dedicated) shuttle orbiter mission.

AUTONOMOUS FREE FLIER MISSION OPERATION

The concept for the CDSF flight mission control and data handling system does not define an interactive telescience experimentation operation capability. Candidate experiments defined for the 5 year lease period do not appear to be conceived with this operational capability in mind. Standard NSTS bandwidth video is provided for interactive mission sequence planning using on board programmed command generation and control methods and techniques currently being implemented for unmanned near earth and planetary spacecraft science missions.

APPENDIX A

STUDY MANAGEMENT PLAN FOR THE COMMERCIALLY DEVELOPED SPACE FACILITY

NASA
National Aeronautics and
Space Administration
Washington, D.C.
20546

SEP 21 1988

Reply to Attn of: M

TO: Marshall Space Flight Center
Attn: DA01/Director

Langley Research Center
Attn: 0100/Director

FROM: M/Associate Administrator for Space Flight

SUBJECT: Commercially Developed Space Facility (CDSF) Studies

The Office of Space Flight (OSF) has been assigned the overall responsibility for directing NASA studies for the CDSF as delineated in the enclosed plan. Per telecon agreement reached by Messrs. George Abbey, Jack Lee, and Paul Holloway on July 8, 1988, in-house study support work will be conducted by the Langley Research Center (LaRC), and subsequent procurement and program implementation for CDSF will be the responsibility of the Marshall Space Flight Center (MSFC). MSFC, therefore, will be an active participant in the studies to assure program implementation continuity.

As the plan indicates, the objective is to release the CDSF RFP in 1989 as soon as the study results have been presented and the CDSF program concept is approved by the Congress. This program is of great interest to the Administration and the Congress, and it is important that all study activities be coordinated through OSF at NASA Headquarters.

Thank you for your cooperation.

Richard H. Truly

Enclosure

cc:
AD/Mr. Myers
M/Mr. Abbey
M/Mr. Hoodless
C/Mr. Rose
E/Dr. Fisk
MSFC/DD01/Mr. Lee
LaRC/0100/Mr. Holloway

NASA

STUDY MANAGEMENT PLAN
FOR
THE COMMERCIALLY DEVELOPED SPACE FACILITY
(CDSF)

National Aeronautics and
Space Administration
Washington, D C 20546

STUDY MANAGEMENT PLAN FOR THE COMMERCIALLY DEVELOPED SPACE FACILITY (CDSF)

Approved: Dale D Myers **Date:** 9/16/88
Deputy Administrator of NASA

INTRODUCTION

As a result of Congressional direction, studies are to be initiated to develop information and recommendations for the Commercially Developed Space Facility (CDSF). These studies were requested to be performed and recommendations provided as a basis for making decisions concerning the CDSF concept.

PURPOSE

The CDSF management plan will: (1) Identify the studies to be performed, (2) Outline the scope of the respective studies, (3) Designate the responsible organization to manage the studies, (4) Define the schedule of activities to support the effort., and (5) Define the study statements of work.

STUDIES TO BE PERFORMED

Two studies are to be performed based on government lease of the CDSF. These studies are in accordance with the Congressional request. They are:

(1) National Research Council (NRC) Study of the CDSF requirements, policy and technical characteristics

(2) National Academy of Public Administration (NAPA) study of CDSF program cost.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

SCOPE OF STUDIES

NRC STUDY

The NRC will conduct an independent study to address the scientific and commercial value to the nation of developing a CDSF prior to and concurrent with the operation of the space station; and the technical characteristics that would assure its optimal use. A draft of the Statement of Work is attached as Enclosure #1.

NAPA STUDY

NAPA will conduct an independent study of the CDSF to estimate program cost to the government for the design, development, production, operation and utilization of the CDSF. Various options concerning the lease arrangement will be assessed as defined in the Statement of Work. A draft of the Statement of Work is attached as Enclosure #2.

STUDY RESPONSIBILITY

Overall responsibility for total study effort shall be managed by the Office of Space Flight (OSF), Director of the Commercially Developed Space Facility, Ralph M. Hoodless, Jr. at 453-2513.

The respective studies shall be managed as follows:

The **NRC STUDY** shall be contracted and managed from **OSF**. The point of contact is Ralph M. Hoodless, Jr. (453-2513). Support to the study will be provided primarily from OSF and the Office of Space Science and Application OSSA.

The **NAPA STUDY** shall be contracted and managed from **OSF**. The point of contact is Ralph M. Hoodless, Jr (453-2513). Support to the study will be provided primarily from OSF and the Office of Commercial Programs (OCP).

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

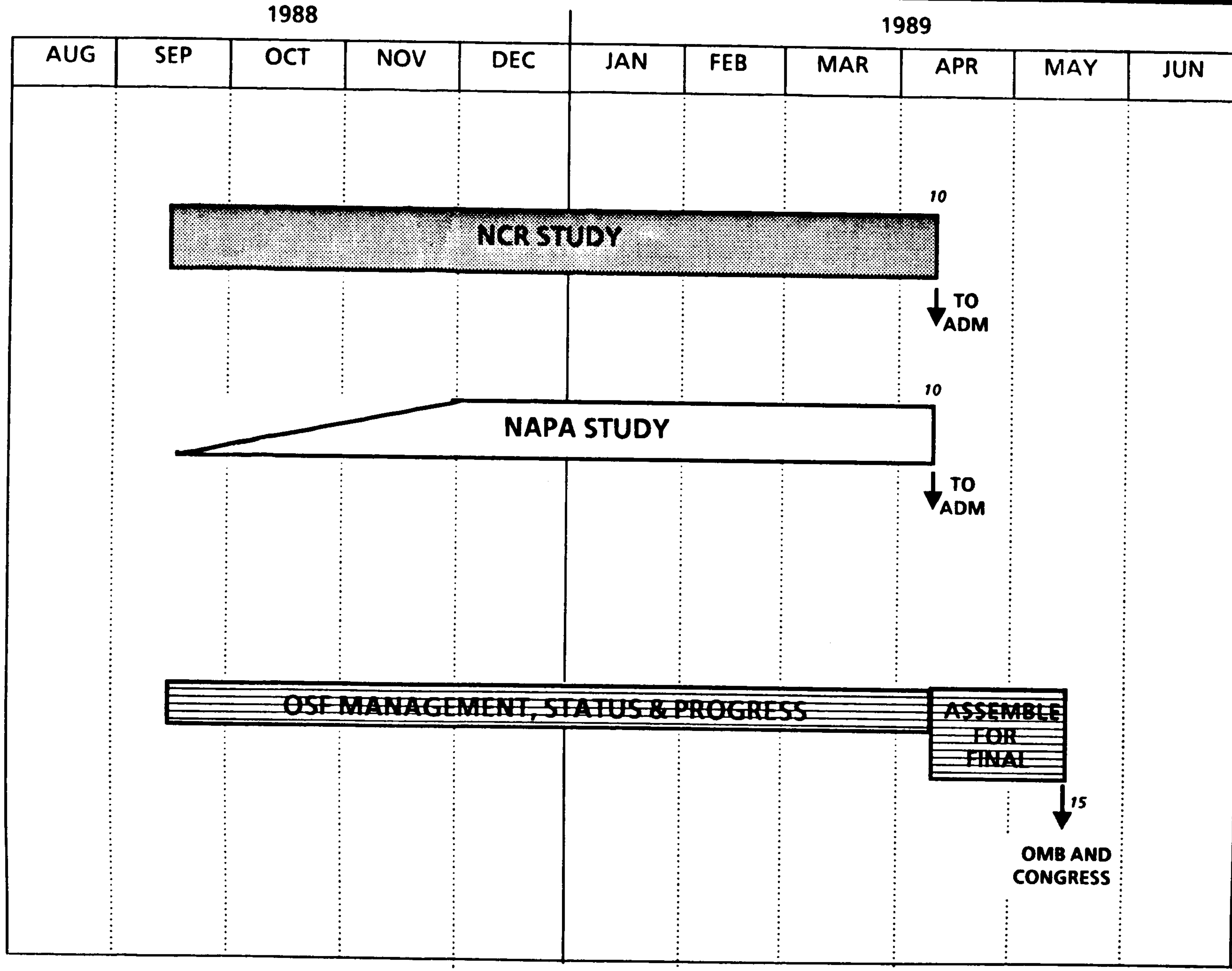
SCHEDULE

The NRC STUDY shall be initiated immediately by OSF and final results provided to the NASA Administrator on or before April 10, 1989. Intermediate milestones prior to this review shall be developed.

The NAPA STUDY shall be initiated in September 1988 by OSF and final results provided to the NASA Deputy Administrator on or before April 10, 1989. Intermediate milestones shall be developed.

A summary of all the study findings, conclusions, and recommendations shall be prepared for a final briefing to the Congressional Committees/staff and the Office of Management and Budget on or before May 15, 1989.

CDSF STUDY PLAN



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PROGRESS REVIEWS TO THE CONGRESS

The Director of the CDSF program shall provide informal progress or status reviews to the various committees/subcommittees of the Congress and the Office of Management and Budget or their designated staff.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

STATEMENT OF WORK
NRC STUDY

The NATIONAL RESEARCH COUNCIL (NRC) shall conduct an independent study of the Commercialiy Developed Space Facility (CDSF) that addresses the following issues:

(1) The scientific and commercial benefit to the nation of developing a commercially developed space facility prior to and concurrent with Space Station operations.

(2) Definition of the criteria for optimum use.

(3) The technical characteristics of a CDSF that would enable its optimum use.

The study shall include the following assessments:

- The planned and anticipated microgravity research and manufacturing requirements of the federal government and commercial users prior to and concurrent with the achievement of space station operations. Power, duration, micro G level shall be evaluated. Some indication of the quantity or percentage of the total that requires long duration in the FY 92 to 97 time period shall be assessed to identify unique requirements for a free flyer. Issues such as automation, re-entry G level, etc. shall be considered.

- How and to what extent existing, planned, and proposed capabilities and infrastructure could support these requirements. This shall include an assessment of the capabilities, and potential benefits of a CDSF, Spacelab, Spacehab, Extended Duration Orbiter, free-flying spacecraft, Expendable Launch Vehicles, and any feasible combination of these capabilities and infrastructure.

- The state of space automation technology and its relevance to the capabilities for a CDSF.

- A comparison of the microgravity research requirements projections based on the maintenance of the Space Station Program's currently planned schedule..

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

STATEMENT OF WORK
NRC STUDY (CONTINUED)

- The relationship of a CDSF to other proposed facilities of a similar nature.

- The effect a commitment to the CDSF would have on the current space transportation system launch schedule.

- The benefit to the nation of providing an orbiting microgravity research and manufacturing capability as early as possible.

The study shall be completed and conclusions and recommendations provided to the Administrator of NASA on or before April 10, 1989. Documentation of the study details, conclusions, recommendations and findings are required in a final report.

ENCLOSURE #1

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

STATEMENT OF WORK
NAPA STUDY

The NATIONAL ACADEMY OF PUBLIC ADMINISTRATION (NAPA) shall conduct an independent study of the Commercially Developed Space Facility (CDSF) that:

- Provides an estimate of the development, operations, and other costs to the government associated with the CDSF, and the estimated lease cost per year for five years which must be paid by the government to meet investment criteria for a viable business.

- Assesses the likelihood that a CDSF would become commercially self-sustaining and an estimate of when that could occur.

- Considers, per the lease option, the practicability of reducing on a yearly basis the level of government lease operations during the years of operation of a CDSF, instead of providing for a flat level of lease obligations.

- Considers, per the lease option, the practicability of making the minimum levels of government lease options in the years of operation of a CDSF contingent on the attainment by the CDSF operator, of certain minimum levels of firm contract commitments with entities other than the United States Government.

- Assesses how a decision by the government to lease facilities on a CDSF might effect the viability of other existing or proposed commercial microgravity facilities.

Periodic progress and status briefings are required.

The study shall be completed and conclusions and recommendations provided to the Administrator of NASA on or before April 10, 1989. Documentation of the study details, conclusions, recommendations and findings are required in a final report.

ENCLOSURE #2

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IN-HOUSE STUDY MANAGEMENT PLAN
FOR
THE COMMERCIALLY DEVELOPED SPACE FACILITY
(CDSF)

National Aeronautics and
Space Administration
Washington, D C 20546

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IN-HOUSE STUDY MANAGEMENT PLAN
FOR
THE COMMERCIALLY DEVELOPED SPACE FACILITY
(CDSF)

Approved: Dale D. Myers **Date:** 9/16/88
Deputy Administrator of NASA

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

INTRODUCTION

As a result of Congressional direction, studies will be initiated to develop information and recommendations for the Commercially Developed Space Facility (CDSF). These studies were requested to be performed and recommendations provided as a basis for making decisions concerning the CDSF concept. Two studies will be made by independent sources {National Research Council (NRC) and the National Academy of Public Administration (NAPA)}. NASA Will provide in-house concept definition studies to support the CDSF Source Evaluation Board activities.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

PURPOSE

This study management plan will: (1) Identify the in-house studies to be performed, (2) Outline the scope of the in-house studies, (3) Designate the responsible organizations to manage and support the studies, (4) Define the schedule of activities to support the effort., and (5) Define the in-house study statements of work.

IN-HOUSE STUDIES TO BE PERFORMED

In-house studies will be performed based on government lease of the CDSF. Two initial concepts have been determined by NASA to be necessary for a comprehensive effort. The results of these two studies will be merged into a recommend CDSF configuration and the supporting data made available to the Source Evaluation Board (SEB) at MSFC for proposal evaluation.

(1) Concept #1 definition study of the CDSF is defined by the functional performance specifications in the March 24, 1988 draft RFP at the SEB at MSFC.

(2) Concept #2 definition study of the CDSF is based on minimum assumed capabilities to "bracket" the accommodation of requirements (Experiment volume approximately 20% of Concept #1).

Results of Concepts #1 & 2 will be compared with requirements as inferred from NRC advice. As a result, NASA will modify the current draft RFP as required for a cost effective CDSF.

SCOPE OF IN-HOUSE STUDIES

CONCEPT #1 DEFINITION STUDY (BASED ON DRAFT RFP FUNCTIONAL PERFORMANCE SPECIFICATIONS)

This study will define and describe the concepts for both the internal and external general characteristics of the CDSF to include the physical size, weight, and system/subsystem details. The study will also generate credible operational scenarios, characteristics, and constraints, and provide an initial estimate of the cost of design, development, production, and operation of this CDSF. Launch costs, training, etc. will be included. A draft of the Statement of Work for this study is attached as Enclosure #1.

CONCEPT #2 DEFINITION STUDY (SMALLER FREE FLYER)

This study will define and describe the concepts for both the internal and external general characteristics of a smaller CDSF to include the physical size, weight and system/subsystem details, generate credible operational scenarios, characteristics, and constraints, and provide an initial estimate of the cost of design, development, production, and operation of this CDSF. This concept will bracket the lower end of the expected capability requirements, initially assumed to be 20% of the available experiment volume of Concept #1. Launch costs, training, etc. will be included. A draft of the Statement of Work for this study is attached as Enclosure #2.

STUDY RESPONSIBILITY

Overall responsibility for this study effort shall be managed by the Office of Space Flight (OSF), Director of the Commercially Developed Space Facility, Ralph M. Hoodless, Jr. at 453-2513. The Langely Research Center is assigned the lead role for the studies with technical and cost support provided as required from MSFC. Final costing will be validated by NAPA.

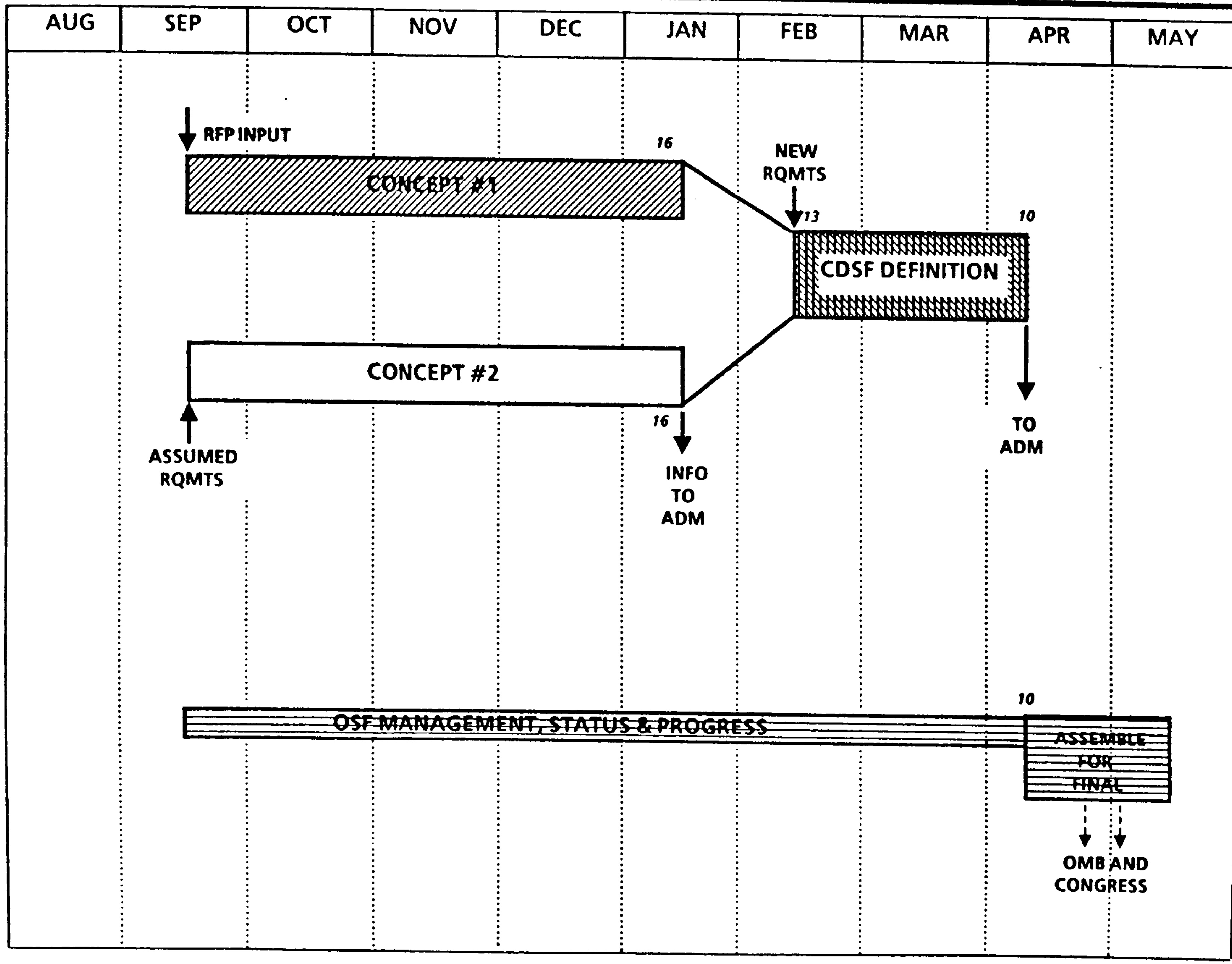
SCHEDULE

The CONCEPT #1 DEFINITION STUDY based on the March 24, 1988 draft RFP requirements shall be initiated immediately with preliminary findings and conclusions provided to headquarters by January 16, 1989. The findings of this study shall be considered together with the findings of Concept #2 definition study.

The CONCEPT #2 DEFINITION STUDY based initially on assumptions, and later updated, shall be initiated immediately with preliminary findings and conclusions provided to headquarters by January 16, 1989. These findings, together with the findings of the Concept #1 study, will be merged into a baseline definition of CDSF based on requirements which NASA expects to come out of the NRC studies. The merged study shall begin on or about February 13, 1989 with findings, recommendations, and conclusions provided to headquarters by April 10, 1989. A final report is required to document the initial Concept #1 and #2 study findings and conclusions as well as the details and results of the definition of the CDSF. The final report shall be provided by April 28, 1989 and shall contain any changes made during the briefings to headquarters on April 10, 1989.

A summary of all the study findings, conclusions, and recommendations shall be prepared by OSF for a final briefing to the Congressional committees/staff and the Office of Management and Budget on or before May 15, 1989.

CDSF IN-HOUSE STUDY PLAN



PROGRESS REVIEWS TO THE CONGRESS

The Director of the CDSF program shall provide informal progress or status reviews to the various committees/subcommittees of the Congress and the Office of Management and Budget or their designated staff.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

STATEMENT OF WORK
CONCEPT #1 DEFINITION STUDY
(RFP)

In-house concept definition studies of the CDSF are required to complement the NRC and NAPA studies directed by the 100th Congress. Langley Research Center is delegated the lead responsibility for these studies with support provided by MSFC. The general characteristics of the space system shall be consistent with the description in the March 24, 1988 draft RFP being held at the Source Evaluation Board at MSFC.

The study shall be complete and documented with a briefing to HQ on the preliminary findings and conclusions so that Concepts #1 and #2 can be modified for subsequent design and cost analysis. A final report is required and will include the results and changes from the April 10, 1989 HQ briefing (due on or before April 28, 1989).

The study tasks are: (1) define and describe concepts for both the internal and external general characteristics to include the physical size, weight, and system/subsystem details, (2) generate credible operational scenarios, characteristics and constraints, and (3) provide an initial estimate of the cost of design, development, production, and operation of the CDSF Concept #1.

The study shall also provide an estimate of the earliest date that such a facility could be available on orbit.

Periodic progress and status briefings are required for NASA Headquarters described in Figure #1.

A study manager at the center shall be named to be the single point of contact for the study.

NOTE: The NRC study is being tasked to address the technical characteristics of a CDSF that would enable its optimum use. This may require the study to be revised/updated as these results become available.

ENCLOSURE #1

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

STATEMENT OF WORK
CONCEPT #2 DEFINITION STUDY
(SMALLER FREE FLYER)

In-house concept studies for the CDSF are required to complement the NRC and NAPA studies directed by the 100th Congress. Langley Research Center is delegated the lead responsibility for these studies with support provided by MSFC. For the purpose of "bracketing" the low end of the requirements, initial definition for the Concept #2 study will assume 20% of the available experiment volume of the Concept #1 configuration. An update of the requirements will be provided as other study results evolve.

The study shall be complete and documented with a briefing to HQ on the preliminary findings and conclusions so that Concepts #1 and #2 can be modified for subsequent design and cost analysis. A final report is required and will include the results and changes from the April 10, 1989 HQ briefing (due on or before April 28, 1989).

The study tasks are: (1) define and describe concepts for both the internal and external general characteristics to include the physical size, weight, and system/subsystem details, (2) generate credible operational scenarios, characteristics and constraints, and (3) provide an initial estimate of the cost of design, development, production, and operation of the CDSF Concept #2.

The study shall also provide an estimate of the earliest date that such a facility could be available on orbit.

Periodic progress and status briefings are required for NASA Headquarters as described in Figure #1.

A study manager at the center shall be named to be the single point of contact for the study.

NOTE: The NRC study is being tasked to address the technical characteristics of a CDSF that would enable its optimum use. This may require the study to be revised/updated as these results become available.

ENCLOSURE #2

APPENDIX B.

DRAFT REQUEST FOR PROPOSAL NO. 8-1-JA9000 COVERING THE LEASE OF A COMMERCIALLY DEVELOPED SPACE FACILITY

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National Aeronautics and
Space Administration

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama
35812

NASA

Reply to Attn of AP32

DRAFT

MAR 24 1988

TO: All Prospective Offerors

SUBJECT: Request for Proposal 8-1-8-JA-90000 for Commercially Developed Space Facility

NASA, on behalf of the Government, intends to lease on a firm-fixed-price basis volume and related services on a Commercially Developed Space Facility (CDSF) for a period of five years in support of the national objective to commercialize space activities. At least 30% of the facility must be available for commercial use over and above the volume and related services leased to the Government. Specifically, the Government wishes to encourage U.S. private sector involvement in microgravity research, experimentation, and development, as well as in materials processing. We are seeking a way to encourage permanent and successful entry of private enterprise into the space community both as users and developers of the unique space environment and as owners of significant elements of the space infrastructure. It is envisioned an industry owned space facility will permit microgravity activities, with short crew-operated periods (attached-to-orbiter mode) and relatively long periods of unmanned operations (free-flyer mode), commencing no later than 1993. Offerors are being requested to submit a firm fixed price proposal for the Government's lease of 70% of the capacity of a CDSF which meets the minimum specified capabilities as reflected in the Statement of Work for a period of five years. Additionally, the offerors are being requested to submit their approach for accommodating annual Government funding scenarios of $80 million and $140 million (in 1988 dollars) for the five year period. Offerors are encouraged to submit innovative approaches that meet the minimum specified capabilities. NASA intends to administer this contract with minimal oversight. To accomplish these objectives, some unique aspects have been included in the enclosed RFP which should be highlighted:

Private Financing

Selection of an offeror for award of the CDSF contract will require the offeror to demonstrate the capability to manufacture and place the CDSF in service, without resort to Government financing. Failure to provide loan commitments with qualified lenders and/or corporate guarantees sufficient to cover all financial requirements, may result in non-selection of the offeror for award of the contract. The offeror's proposal shall include the CDSF construction costs, servicing and operations costs, planned financing, break even expectations and other elements of financing necessary to demonstrate the offeror's understanding of the overall business arrangement and the offeror's assumptions as to commercial payload contributions.

STS Launch

The contractor will be responsible for arranging and paying for space transportation services by a separate Launch Services Agreement. NASA will entertain deferred payment arrangements for the Space Transportation System (STS).

Government Funding

Funding for the proposed lease is not currently available. The Administration intends to seek legislation which would provide advanced appropriations to become available when a fully integrated flightworthy facility is available for lease. It is the Administration's intention to seek, on an annual basis, additional appropriations to cover an appropriate level of Government liability in the event of termination for the convenience of the Government.

Indemnification

Indemnification for third party liability by the Government will not be available to the successful offeror.

Prequalification Criteria

Since the purpose of this procurement is to foster United States industrial development and commercialization in space, participation in this procurement by prime contractors and major subcontractors is restricted to United States industry. Major subcontractor means an entity who performs any effort of $500,000 or more.

Expenses Related to Offeror Submissions

The issuance of the RFP does not commit the Government to pay any cost incurred in the submission of the offer or in making necessary studies or designs for the preparation thereof, nor to contract for service or supplies.

This procurement represents a major step forward to facilitate the commercial involvement in space. Your interest in this program is appreciated.

K.D. Sowell
Contracting Officer

DRAFT

MAR 24 1988

OMB Approval #: 2700-0042.

SOLICITATION, OFFER AND AWARD

1. THIS CONTRACT IS A RATED ORDER UNDER DPAS (15 CFR 350) ▶ RATING: DO-C9 | PAGE 1 OF 86 PAGES

2. CONTRACT NO.	3. SOLICITATION NO.	4. TYPE OF SOLICITATION	5. DATE ISSUED	6. REQUISITION/PURCHASE NO.
	8-1-8-JA-90000	[ ] SEALED BID (IFB) [X] NEGOTIATED (RFP)	3/31/88	1-8-JA-90000

7. ISSUED BY — CODE AP 32-A

Procurement Office
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, AL 35812

8. ADDRESS OFFER TO (If other than Item 7)

NOTE: In sealed bid solicitations "offer" and "offeror" mean "bid" and "bidder"

SOLICITATION

9. Sealed offers in original and 25 copies for furnishing the supplies or services in the Schedule will be received at the place specified in Item 8, or if handcarried, in the depository located in Rm. 238B, Bldg. 4201 until 4:00 (Hour) local time 5/31/88 (Date)

CAUTION - LATE Submissions, Modifications, and Withdrawals: See Section L, Provision No. 52.214-7 or 52.215-10. All offers are subject to all terms and conditions contained in this solicitation.

10. FOR INFORMATION CALL ▶ A. NAME: K.D. Sowell | B. TELEPHONE NO. (Include area code) (NO COLLECT CALLS): 205-544-0360

11. TABLE OF CONTENTS

DRAFT MAR 24 1988

OFFER (Must be fully completed by offeror)

NOTE: Item 12 does not apply if the solicitation includes the provisions at 52.214-16, Minimum Bid Acceptance Period.

12. In compliance with the above, the undersigned agrees, if this offer is accepted within ______ calendar days (60 calendar days unless a different period is inserted by the offeror) from the date for receipt of offers specified above, to furnish any or all items upon which prices are offered at the price set opposite each item, delivered at the designated point(s), within the time specified in the schedule.

13. DISCOUNT FOR PROMPT PAYMENT (See Section I, Clause No. 52.232.8)	10 CALENDAR DAYS	20 CALENDAR DAYS	30 CALENDAR DAYS	CALENDAR DAYS
	%	%	%	%

14. ACKNOWLEDGMENT OF AMENDMENTS (The offeror acknowledges receipt of amendments to the SOLICITATION for offerors and related documents numbered and dated)	AMENDMENT NO.	DATE	AMENDMENT NO.	DATE

15A. NAME AND ADDRESS OF OFFEROR — CODE | FACILITY

16. NAME AND TITLE OF PERSON AUTHORIZED TO SIGN OFFER (Type or print)

15B. TELEPHONE NO. (Include area code) | 15C. CHECK IF REMITTANCE ADDRESS IS DIFFERENT FROM ABOVE – ENTER SUCH ADDRESS IN SCHEDULE | 17. SIGNATURE | 18. OFFER DATE

DRAFT MAR 24 1988

AWARD (To be completed by Government)

19. ACCEPTED AS TO ITEMS NUMBERED | 20. AMOUNT | 21. ACCOUNTING AND APPROPRIATION

22. AUTHORITY FOR USING OTHER THAN FULL AND OPEN COMPETITION:
[ ] 10 U.S.C. 2304(c)( ) [ ] 41 U.S.C. 253(c)( )

23. SUBMIT INVOICES TO ADDRESS SHOWN IN (4 copies unless otherwise specified) ▶ ITEM

24. ADMINISTERED BY (If other than Item 7) CODE

25. PAYMENT WILL BE MADE BY — CODE BF52

Financial Management Office
George C. Marshall Space Flight Center, NASA
Marshall Space Flight Center, AL 35812

26. NAME OF CONTRACTING OFFICER (Type or print) | 27. UNITED STATES OF AMERICA (Signature of Contracting Officer) | 28. AWARD DATE

IMPORTANT – Award will be made on this Form, or on Standard Form 26, or by other authorized official written notice.

NSN 7540-01-152-8064
PREVIOUS EDITION NOT USABLE

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33-133

STANDARD FORM 33 (REV. 4-85)
Prescribed by GSA
FAR (48 CFR) 53.214(c)

SECTION A-1

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SECTION B

SUPPLIES OR SERVICES AND PRICES/COSTS

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SECTION B

SUPPLIES OR SERVICES AND PRICES/COSTS

ARTICLE B-1--DESCRIPTION OF SERVICES AND PRICES/COSTS

The Contractor shall provide a Commercially Developed Space Facility (CDSF) and related services for lease by the Government and Commercial users. This contract covers the lease of ___ of the usable volume of the CDSF and related services as described in Attachment J-1, Statement of Work, by the Government.

ARTICLE B-2--CONSIDERATION AND PAYMENT

The Contractor shall be paid a firm-fixed-price of $ ________ upon satisfactory performance and Government acceptance of the lease services of this contract. The firm-fixed-price covers the lease of ___ of the usable volume of the CDSF for a period of 60 months commencing with the successful delivery of a certified, Launch Ready CDSF to the Launch Site and completion of all final safety and performance certifications. Monthly payments in the amount of $ ___________ are authorized upon acceptance of the services. Specific services and duration of the leased volume is further defined in Attachment J-1.

ARTICLE B-3--OPTION FOR ADDITIONAL CDSF SERVICES

If usable volume and related services are available beyond the initial 60 months, the Government may, at its option, lease the CDSF volume and related services at the following firm-fixed-price rates:

Monthly Rate Per Each Percentage of Volume and Related Services

Volume and Related Services	1st Year	2nd Year	3rd Year	4th Year	5th Year
1% - 10%					
11% - 25%					
26% - 50%					
51% - 70%					
71% - 100%					

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SECTION C

DESCRIPTION/SPECIFICATIONS/STATEMENT OF WORK

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SECTION C

DESCRIPTION/SPECIFICATIONS/STATEMENT OF WORK

ARTICLE C-1--STATEMENT OF WORK

The Contractor shall, on the terms and conditions hereinafter more particularly set forth, furnish the necessary management, labor, facilities, and materials and do all things necessary and/or incidental to performance of the work set forth in PART I - THE SCHEDULE, PART II - CONTRACT CLAUSES, and PART III - EXHIBITS AND OTHER ATTACHMENTS.

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SECTION D

PACKING AND MARKING

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SECTION D

PACKING AND MARKING

ARTICLE D-1--MARKING

Packaging shall be labeled with a warning if potentially hazardous or delicate material is involved.

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SECTION E

INSPECTION AND ACCEPTANCE

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SECTION E

INSPECTION AND ACCEPTANCE

ARTICLE E-1--ACCEPTANCE

Acceptance of Lease Services shall be by the Contracting Officer or his/her duly authorized representative. Complete compliance with the provisions of Article E-2, titled "Definition of Acceptable Service", will demonstrate that service has been delivered.

ARTICLE E-2--DEFINITION OF ACCEPTABLE SERVICE

The CDSF shall meet the requirements specified in Paragraph 3.0 of Attachment J-1, Statement of Work.

ARTICLE E-3--SERVICE OUTAGE CREDITS

Service outages is that period of time during which the CDSF and associated services do not fully meet the specified performance requirements of the Statement of Work.

Service outages which are scheduled by the Contractor, and agreed to by the Government, in order to allocate peak power requirements on a temporary basis to one or more experiments, without adversely affecting Government experiments, will not be considered service outages under this article.

Service outage credits will be based on an effectiveness level derived from the actual service hours available during the monthly period.

(Offeror shall propose service outage plan)

In the event that a service outage results in a total loss of payload or experiment, that portion of the lease related to said payload or experiment shall be forfeited.

For total CDSF service outages NASA shall not be liable for payment of the scheduled service payments. In addition, NASA shall have the right to unilaterally extend the scheduled period of service for a NASA payload, for a like period.

In any event, NASA shall retain all its rights under any other provision of the contract, including the clause titled "Default."

(Offeror is invited to propose alternate)

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SECTION F

DELIVERIES OR PERFORMANCE

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SECTION F

DELIVERIES OR PERFORMANCE

ARTICLE F-1--DELIVERIES

The Contractor shall provide the documentation, software, hardware and pre-launch and on-orbit services specified in Attachment J-1, Statement of Work.

ARTICLE F-2--SHIPPING INSTRUCTIONS

Shipment of the items called for herein shall be as follows:

Item	Address	Marked For

(Shipping Instructions will be provided the Contracting Officer, as required. All deliveries shall be F.O.B. Destination.)

ARTICLE F-3--PERIOD OF PERFORMANCE

The period of the contract shall begin with the contract award date through ________________. The Contractor shall provide 60 calendar months of CDSF services during the period _____________ through ________________.

ARTICLE F-4--PLACE OF PERFORMANCE

The Contractor shall perform the work under this contract at its facilities located at , and at such other locations as may be approved in writing by the Contracting Officer.

ARTICLE F-5--F.O.B. DESTINATION (APR 1984) (52.247-34)

(a) The term "f.o.b. destination," as used in this clause means -

(1) Free of expense to the Government, on board the carrier's conveyance, at a specified delivery point where the consignee's facility (plant, warehouse, store, lot, or other location to which shipment can be made) is located; and

(2) Supplies shall be delivered to the destination consignee's wharf (if destination is a port city and supplies are for export), warehouse unloading platform, or receiving dock, at the expense of the Contractor. The Government shall not be liable for any delivery, storage, demurrage, accessorial, or other charges involved before the actual delivery (or "constructive placement" as defined in carrier tariffs) of the supplies to

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the destination, unless such charges are caused by an act or order of the Government acting in its contractual capacity. If rail carrier is used, supplies shall be delivered to the specified unloading platform of the consignee. If motor carrier (including "piggyback") is used, supplies shall be delivered to truck tailgate at the unloading platform of the consignee. If the Contractor uses rail carrier or freight forwarder for less than carload shipments, the Contractor shall assure that the carrier will furnish tailgate delivery if transfer to truck is required to complete delivery to consignee.

(b) The Contractor shall -

(1) (i) Pack and mark the shipment to comply with contract specifications; or

(ii) In the absence of specifications, prepare the shipment in conformance with carrier requirements;

(2) Prepare and distribute commercial bills of lading;

(3) Deliver the shipment in good order and condition to the point of delivery specified in the contract;

(4) Be responsible for any loss of and/or damage to the goods occurring before receipt of the shipment by the consignee at the delivery point specified in the contract;

(5) Furnish a delivery schedule and designate the mode of delivering carrier; and

(6) Pay and bear all charges to the specified point of delivery.

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SECTION G

CONTRACT ADMINISTRATION DATA

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SECTION G

CONTRACT ADMINISTRATION DATA

ARTICLE G-1--CONTRACTING OFFICER'S REPRESENTATIVE(S) (APR 1987) (52.202-90)

The Contracting Officer may appoint a Contracting Officer's Representative, or Representatives, to act in his behalf during the performance of this contract. The Representative(s) will be specifically designated by written appointment from the Contracting Officer and will represent the Contracting Officer in the designated phases of the work. The Representative(s) will not be authorized to change any of the terms and conditions of this contract, and shall have such prescribed duties and authorities as specified in writing by the Contracting Officer. A copy of the letter of appointment will be furnished the Contractor.

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SECTION H

SPECIAL CONTRACT REQUIREMENTS

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SECTION H

SPECIAL CONTRACT REQUIREMENTS

ARTICLE H-1--IMPACT OF COMMERCIAL PAYLOADS

The parties recognize that the Contractor may provide CDSF services to non-Government payloads (hereinafter referred to as "commercial payloads") during the period of performance of this contract.

In the event the Contractor's provision of CDSF services to a Government payload or payloads is adversely affected by, or may reasonably be expected to be adversely affected by, the Contractor's provision of services to a commercial payload, or by the commercial payload itself, the Contractor shall immediately take all actions necessary to avoid or abate such interference or impact and ensure or restore full provision of services to the Government payload or payloads.

ARTICLE H-2--RESERVED

ARTICLE H-3--WARRANTY EXCLUSION AND LIMITATION OF DAMAGES

Except as expressly set forth in writing in this contract, or except as provided in the clause entitled, "Contractor Commitments, Warranties, and Representations," if applicable, and except for the implied warranty of merchantability, there are no warranties expressed or implied. In no event will the Contractor be liable to the Government for consequential damages as defined in the Uniform Commercial Code.

ARTICLE H-4--CONTRACTOR REPRESENTATIVE(S)

The Contractor shall designate one of its personnel to act as manager and delegate to this person the complete authority to decide all technical matters connected with this contract. The Contractor shall further designate a second employee as alternate or assistant manager with the authority to act as and upon behalf of the manager in the event of the absence or incapacity of the designated manager. The Contractor shall advise the Contracting Officer in writing of the persons so designated.

ARTICLE H-5--TERMINATION LIABILITY

In the event that this contract is terminated for the convenience of the Government, the maximum amount for which the Government shall be liable under the clause of this contract entitled "Termination for the Convenience of the Government", is as follows:

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Annual Period	Annual Liability	Cumulative Maximum Liability

(Offer shall propose a year by year minimally acceptable termination liability schedule)

Notwithstanding the amounts listed above, upon termination of the contract for convenience, the Government will not be liable for any termination liability which exceeds appropriations available in relevant program areas at the time of termination and nothing in this Request for Proposal (RFP) or any resulting contract may be considered as implying that the Congress will, at a later date, appropriate funds sufficient to meet the termination liabilities proposed above.

To the extent that the Contractor proposes termination liability under this provision, the Contractor shall also propose a corresponding equity value which NASA shall take in the equipment being produced and/or future services to be provided.

ARTICLE H-6--FAILURE TO PROVIDE CDSF SERVICES

For such lease period(s) as the Contractor fails to provide services required by this contract, unless the failure is caused solely by NASA, NASA shall not be liable for payment of the scheduled lease payment. In addition NASA shall have the right to unilaterally extend the scheduled period of lease for the period that the services were not available. In the event of such an extension the rate shall be as specified in ARTICLE B-2, titled "Consideration and Payment."

In any event, NASA shall retain all its rights under any other provision of this contract, including the clause titled "Default".

ARTICLE H-7--CONTRACTOR COMMITMENTS, WARRANTIES AND REPRESENTATIONS

Any written commitment by the Contractor within the scope of this contract shall be binding upon the Contractor. For the purpose of this contract, a written commitment by the Contractor includes the proposal submitted by the Contractor, and specific written modifications to the proposal. Written commitments by the Contractor are further defined as including (1) any warranty or representation made by the Contractor in a proposal as to hardware or software performance and total systems performance, (2) any warranty or representation made by the Contractor concerning the characteristics or items described in (1) above made in any publications, drawings or specifications accompanying or referred to in a proposal, and (3) any modification of or affirmation or representation as to the above which is made by the Contractor in or during the course of negotiations, whether or not incorporated into a formal amendment to the proposal in question.

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ARTICLE H-8--MONTHLY STATUS REPORTS

(The offeror shall propose the terms of this article. The terms of this article will be based on the offeror's project manager submitting a monthly letter under their signature that addresses the summary outlook, status and problems of all activities including a monthly recertification of the schedule.)

ARTICLE H-9--OPTION TO EXTEND THE TERM OF LEASE

If usable volume and related services are available, this lease is renewable in whole or in part at the prices listed in Article B-3 titled, "Option for Additional CDSF Services" at the option of the Government, by the Contracting Officer giving written notice of renewal to the Contractor by the first day of each renewal period or within 30 days after the beginning of the fiscal year in which funds have become available, whichever date is the later; provided that the Contracting Officer shall have given preliminary notice of the Government's intention to renew at least one year before this lease is to expire. Such a preliminary notice of intent to renew shall not be deemed to commit the Government to renewals. If the Government exercises this option for renewal, the contract as renewed shall be deemed to include this option provision. However, the total period of lease under this contract shall not exceed 120 months. Options shall be exercised for periods of not less than one month or not more than twelve months duration.

ARTICLE H-10--SUBLEASE

The Government may sublease any of its allocated volume and related services on the CDSF. With the consent of the developer, Government-leased space may be made available to the developer for re-lease with an appropriate adjustment in the Government lease price.

ARTICLE H-11--GOVERNMENT SURVEILLANCE

(The offeror shall propose a contract Article describing what visibility the Government will have in the design and manufacture of the CDSF.)

ARTICLE H-12--INTERPARTY LIABILITY

The offeror shall propose an interparty liability scheme applicable when the CDSF is in the free flyer mode.*

(*When the CDSF is in the attached mode the Interparty Waiver provisions of the applicable Launch Services Agreement will govern.)

ARTICLE H-13--RIGHTS IN TECHNICAL DATA

A. All technical data (the term to include computer software and documentation thereof) furnished to NASA under this Agreement shall be provided with unlimited rights (the right to use, duplicate, and disclose in any manner for any purpose whatsoever), except as provided in subparagraph B below. Designation of deliverable data as trade secret technical data or copyrighted works pursuant to subparagraph B shall be kept to a minimum in order to meet the multi-faceted disclosure needs of both parties.

B. In the event that the Contractor believes that it is required under this contract to furnish trade secret technical data, the Contractor shall immediately inform the Contracting Officer in writing of such belief and include preliminary substantiation as to the trade secret character of the technical data. The Contractor shall not proceed with delivery of the technical data in question until the Contracting Officer provides written confirmation that the data is indeed required, whereupon a protective notice will be marked or the data prior to delivery, the notice stating that the data may be used and disclosed by NASA, its contractors, subcontractors, and authorized users of its leased facilities, only for the purpose of fulfilling NASA's responsibilities or exercising NASA's rights under this contract. The notice shall also provide that the data shall not be disclosed or transferred to any non-participant in this program without prior permission of the Contractor. For delivered copyrighted works, NASA, its contractors, subcontractors, and authorized users shall have the right to copy consistent with its responsibilities under this contract.

C. There will be no obligation on the part of NASA, its contractors, subcontractors, or authorized users to protect unmarked technical data.

ARTICLE H-14--PATENT INFRINGEMENT

The Contractor is responsible for, and shall indemnify NASA against, any and all patent infringement costs resulting from the development, fabrication, or use of the CDSF. Such costs include costs associated with defending the alleged infringement, as well as any payments or royalties resulting from a patent owner's successful suit. NASA agrees to notify the Contractor of any patent infringement claim as soon as practical after receipt of such information.

ARTICLE H-15--RIGHTS TO INTELLECTUAL PROPERTY DEVELOPED BY NASA

The Contractor shall not acquire any rights to intellectual property developed or used by NASA or its authorized users of the CDSF by virtue of this contract for lease of the facility.

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ARTICLE H-16--PERMITS AND LICENSES

The Contractor shall obtain, and keep effective, all permits and licenses required for performance in accordance with the terms of this contract. Such permits and licenses shall include, but not be limited to, those required by the Federal, State, or Local Government authorities, or sub-division thereof, or of any other duly constituted public authority. Further, the Contractor shall comply with all applicable laws, regulations and ordinances as in effect on the date of this contract.

ARTICLE H-17--HOLD HARMLESS

Contractor shall indemnify and hold harmless the Government and its officers and employees from and against any and all liabilities, damages, and losses, including costs and expenses in connection therewith for death of or injury to any third persons whomever and for the loss of, damage to or destruction of any property whatsoever caused by, arising out of or in anyway connected with the launch or operation of the CDSF. If the Contractor purchases and maintains comprehensive general liability insurance such insurance shall name the Government as an insured party. Such an insurance policy shall include a waiver of the insurance carrier's rights of subrogation against the Government.

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SECTION I

CONTRACT CLAUSES

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SECTION I

CONTRACT CLAUSES

ARTICLE I-1--CLAUSES INCORPORATED BY REFERENCE (APR 1984) (52.252-2)

This contract incorporates the following clauses by reference, with the same force and effect as if they were given in full text. Upon request, the Contracting Officer will make their full text available.

A. FEDERAL ACQUISITION REGULATION (48 CFR CHAPTER 1) CLAUSES

Provision Clause No.	Title	Date
52.202-1	Definitions	Apr. 1984
52.203-1	Officials Not to Benefit	Apr. 1984
52.203-3	Gratuities	Apr. 1984
52.203-5	Covenant Against Contingent Fees	Apr. 1984
52.203-6	Restrictions on Subcontractor Sales to the Government	Jul. 1985
52.203-7	Anti-Kickback Procedures	Feb. 1987
52.204-2	Security Requirements	Apr. 1984
52.212-8	Defense Priority and Allocation Requirements	May 1986
52.215-1	Examination of Records by Comptroller General	Apr. 1984
52.215-2	Audit -- Negotiation	Apr. 1984
52.215-33	Order of Precedence	Jan. 1986
52.219-8	Utilization of Small Business Concerns and Small Disadvantaged Business Concerns	Jun. 1985
52.219-13	Utilization of Women-Owned Small Businesses	Aug. 1986
52.220-3	Utilization of Labor Surplus Area Concerns	Apr. 1984
52.222-20	Walsh-Healey Public Contracts Act	Apr. 1984
52.222-26	Equal Opportunity	Apr. 1984
52.222-28	Equal Opportunity Preaward Clearance of Subcontracts	Apr. 1984
52.222-35	Affirmative Action for Special Disabled and Vietnam Era Veterans	Apr. 1984
52.222-36	Affirmative Action for Handicapped Workers	Apr. 1984
52.222-37	Employment Reports on Special Disabled Veterans and Veterans of the Vietnam Era	Jan. 1988
52.223-2	Clean Air and Water	Apr. 1984
52.229-3	Federal, State, and Local Taxes	Apr. 1984
52.229-5	Taxes -- Contracts Performed in U.S. Possessions or Puerto Rico	Apr. 1984

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FEDERAL ACQUISITION REGULATION (48 CFR CHAPTER 1) CLAUSES
(Continued)

Provision Clause No.	Title	Date
52.232-11	Extras	Apr. 1984
52.232-17	Interest	Apr. 1984
52.232-18	Availability of Funds	Apr. 1984
52.232-23	Assignment of Claims	Jan. 1986
52.233-1	Disputes (Apr. 1984) -- Alternate I (Apr. 1984)	
52.233-3	Protest After Award	Jun. 1985
52.243-7	Notification of Changes	Apr. 1984
52.244-1	Subcontracts (Fixed-Price Contracts)	Jan. 1986
52.245-1	Property Records	Apr. 1984
52.246-4	Inspection of Services -- Fixed-Price (Jul. 1985)	
52.246-25	Limitation of Liability -- Services (Apr. 1984)	
52.249-2	Termination for Convenience of the Government (Fixed Price)	Apr. 1984
52.249-8	Default (Fixed-Price Supply and Service)	Apr. 1984

B. NASA/FAR SUPPLEMENT (48 CFR CHAPTER 18) CLAUSES

Clause Number	Title	Date
18-52.204-70	Report on NASA Subcontracts	Apr. 1984
18-52.212-70	Notice of Delay	Apr. 1984
18-52.223-70	Safety and Health	Apr. 1984
18-52.223-71	Frequency Authorization	Apr. 1984
18-52.228-72	Inter-Party Waiver of Liability During STS Operations (Oct. 1984)	
18-52.231-70	Pricing of Adjustments (Apr. 1984)	
18-52.232-71	Invoices	Oct. 1987
18-52.245-70	Acquisition of Existing Government Equipment	Aug. 1985

ARTICLE I-2--PROVISIONS INCORPORATED BY REFERENCE

Section K - "Representations, Certifications, and Other Statements of Offerors or Quoters" is hereby incorporated in its entirety by reference, with the same force and effect as if they were given in full text.

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ARTICLE I-3--SECTION I FULL TEXT CLAUSES

The following clauses are attached hereto in full text:

Clause Number	Title	Date
52.223-3	Hazardous Material Identification and Material Safety Data	Aug. 1987
52.232-1	Payments (Apr. 1984) -- As Modified by 18-52.232-1 NASA FAR Supplement (Apr. 1984)	
52.243-1	Changes -- Fixed Price (Aug. 1987) -- As Modified by 18-52.243-1 NASA FAR Supplement (Apr. 1984)	
18-52.232-78	Payment Information (Oct. 1987) (MODIFICATION) -- MSFC (11/12/87)	
18-52.252-70	Compliance with NASA/FAR Supplement	Apr. 1984
18-52.252-71	Federal Acquisition Regulation References	May 1986

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52.223-3 HAZARDOUS MATERIAL IDENTIFICATION AND MATERIAL SAFETY DATA (AUG 1987)

(a) The Contractor agrees to submit a Material Safety Data Sheet (Department of Labor Form OSHA-20), as prescribed in Federal Standard No. 313B, for all hazardous material 5 days before delivery of the material, whether or not listed in Appendix A of the Standard. This obligation applies to all materials delivered under this contract which will involve exposure to hazardous materials or items containing these materials.

(b) "Hazardous material," as used in this clause, is as defined in Federal Standard No. 313B, in effect on the date of this contract.

(c) Neither the requirements of this clause nor any act or failure to act by the Government shall relieve the Contractor of any responsibility or liability for the safety of Government, Contractor, or subcontractor personnel or property.

(d) The Contractor shall comply with applicable Federal, state, and local laws, codes, ordinances, and regulations (including the obtaining of licenses and permits) in connection with hazardous material.

(e) The Government's rights in data furnished under this contract with respect to hazardous material are as follows:

(1) To use, duplicate, and disclose any data to which this clause is applicable. The purposes of this right are to (i) apprise personnel of the hazards to which they may be exposed in using, handling, packaging, transporting, or disposing of hazardous materials; (ii) obtain medical treatment for those affected by the material; and (iii) have others use, duplicate, and disclose the data for the Government for these purposes.

(2) To use, duplicate, and disclose data furnished under this clause, in accordance with subparagraph (e)(1) above, in precedence over any other clause of this contract providing for rights in data.

(3) That the Government is not precluded from using similar or identical data acquired from other sources.

(4) That the data shall not be duplicated, disclosed, or released outside the Government, in whole or in part for any acquisition or manufacturing purpose, if the following legend is marked on each piece of data to which this clause applies —

"This is furnished under United States Government Contract No. .... and shall not be used, duplicated, or disclosed for any acquisition or manufacturing purpose without the permission of .... This legend shall be marked on any reproduction of this data."

(End of Legend)

(5) That the Contractor shall not place the legend or any other restrictive legend on any data which (i) the Contractor or any subcontractor previously delivered to the Government without limitations or (ii) should be delivered without limitations under the conditions specified in the Federal Acquisition Regulation in the clause at 52.227-14, Rights in Data.

(f) The Contractor shall insert this clause, including this paragraph (f), with appropriate changes in the designation of the parties, in subcontracts at any tier (including purchase designations or purchase orders) under this contract involving hazardous material.

(End of Clause)

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52.232-1 PAYMENTS (APR 1984) -- AS MODIFIED BY 18-52.232-1 NASA FAR SUPPLEMENT (APR 1984)

The Government shall pay the Contractor, within 30 days after receipt of proper invoices, as determined under the "Invoices" clause of this contract, the prices stipulated in this contract for supplies delivered and accepted or services rendered and accepted, less any deductions provided in this contract. Unless otherwise specified in this contract, payment shall be made on partial deliveries accepted by the Government if --

(a) The amount due on the deliveries warrants it; or

(b) The Contractor requests it and the amount due on the deliveries is at least $1,000 or 50 percent of the total contract price.

(End of Clause)

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52.243-1 CHANGES -- FIXED-PRICE (AUG 1987)

(a) The Contracting Officer may at any time, by written order, and without notice to the sureties, if any, make changes within the general scope of this contract in any one or more of the following:

(1) Drawings, designs, or specifications when the supplies to be furnished are to be specially manufactured for the Government in accordance with the drawings, designs, or specifications.

(2) Method of shipment or packing.

(3) Place of delivery.

(b) If any such change causes an increase or decrease in the cost of, or the time required for, performance of any part of the work under this contract, whether or not changed by the order, the Contracting Officer shall make an equitable adjustment in the contract price, the delivery schedule, or both, and shall modify the contract.

(c) The Contractor must assert its right to an adjustment under this clause within 30 days from the date of receipt of the written order. However, if the Contracting Officer decides that the facts justify it, the Contracting Officer may receive and act upon a proposal submitted before final payment of the contract.

(d) If the Contractor's proposal includes the cost of property made obsolete or excess by the change, the Contracting Officer shall have the right to prescribe the manner of the disposition of the property.

(e) Failure to agree to any adjustment shall be a dispute under the Disputes clause. However, nothing in this clause shall excuse the Contractor from proceeding with the contract as changed.

(End of Clause)

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18-52.232-78 PAYMENT INFORMATION (OCT 1987) (MODIFICATION) -- MSFC (11/12/87)

(a) Payments under the contract will be made either by check or by wire transfer at the option of the Government.

(b) Within ten (10) days after award, except as specified in paragraph (c) below, the Contractor shall complete the "Company Information" section of the TFS Form 3881, have its financial institution complete the "Financial Institution Information" section, and forward the form to the paying office shown in the contract.

(c) If the Contractor has previously submitted TFS Form 3881 in accordance with paragraph (b) above, the information thereon will be used for this contract. Therefore, resubmittal of the form is not necessary unless the Contractor desires to change payment information or revised information is requested by the Contracting Officer or the paying office.

(End of Clause)

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18-52.252-70 COMPLIANCE WITH NASA FAR SUPPLEMENT (APR 1984)

Any statements in this contract requiring compliance with specific provisions of the Federal Acquisition Regulation (e.g., Subpart 45.5) shall be construed to also require compliance with any corresponding implementing or supplementing provisions in the NASA FAR Supplement in effect on the date of this contract.

(End of Clause)

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18-52.252-71 FEDERAL ACQUISITION REGULATION REFERENCES (MAY 1986)

This solicitation/contract may contain numerical references to segments of the Federal Acquisition Regulation (FAR) that, as of April 1, 1984, had not been promulgated or fully distributed. Pending such action these segments have been published in NASA Procurement Notice 85-17 and thereby incorporated into the NASA FAR Supplement temporarily. Consequently, a numerical reference to such segments of the FAR contained in this solicitation/contract shall be deemed to refer to the equivalent reference, prefixed by the number "18-" as set forth in NASA Procurement Notice 85-17; e.g., a reference to FAR 22.10 would be referring to 18-22.10 as set forth in NASA Procurement Notice 85-17.

(End of Clause)

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SECTION J

ATTACHMENT(S)

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ATTACHMENT J-1

STATEMENT OF WORK

COMMERCIALLY DEVELOPED SPACE FACILITY

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ATTACHMENT J-1
STATEMENT OF WORK
COMMERCIALLY DEVELOPED SPACE FACILITY

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1.0 INTRODUCTION

In order to encourage private sector involvement in the commercial development of a space-based infrastructure to support microgravity research, experimentation, development, materials processing, and production, the Government intends to lease services on-board a Commercially Developed Space Facility for a five year period. These services and associated requirements are described below. A key feature of this solicitation is its commercial services nature, i.e., the Government will not take title of any portion of the on-orbit facility, nor will it incur lease costs until certified hardware, ready for launch, and meeting the specifications listed below is delivered to the launch site and certified for integration into the Orbiter. (The contractor may elect to use an Expendable Launch Vehicle (ELV) for launch. It should be noted, however, that on-orbit crew operations/servicing will be accomplished while attached to the Orbiter.)

2.0 LEASED SERVICES

2.1 The contractor shall provide a Commercially Developed Space Facility (CDSF) including Ground Support Equipment (GSE), Airborne Support Equipment (ASE), servicing module if used, etc., and related services for lease by the Government and commercial users. This Statement of Work covers the lease of the following services: (1) 70%* of the usable volume and related capabilities of the CDSF by the Government; (2) all flight control and mission operation services and (3) communications and data services for the CDSF and experiments on orbit.

2.1.1 The offeror is responsible for the initial launch of the CDSF. The following services associated with the initial launch are included in the lease.

a. Launch services and the Government prorated share of any NSTS Optional Services associated with the initial deployment. (NSTS Optional Services and other tasks that the CDSF developer may require NASA to perform shall be identified.)

b. Ground integration/test and checkout services necessary to permit the fully integrated CDSF to go directly to the launch site for initial launch processing.

c. Analytical and physical integration of Government and Government-sponsored experiments and hardware into the CDSF for the initial payload complement.

d. Return of the Government experiments associated with the initial payload complement.

e. Re-entry, return, or disposal of the CDSF at the end of its lease or useful operational life (whichever is greater).

* The 70% is applicable to the baseline proposal, only.

2.1.2 The following services associated with subsequent launches (revisits) are not included in the lease, but are Standard and/or Optional CDSF Services to be prorated among the Government, commercial customers and the CDSF developer according to revisit usage and specific requirements.

a. Launch services

b. NSTS Optional Services

c. Ground integration/test and checkout services

d. Analytical and physical integration of experiment hardware and experiment racks into the CDSF

e. Experiment Payload return

2.2 (See Appendix A for an overview of a typical scenario for a CDSF mission, which is provided for illustration only.)

3.0 SYSTEM PERFORMANCE REQUIREMENTS

The developer will provide the user/tenant services sufficient to accommodate a range of microgravity research and manufacturing efforts. The provision of such services will be as proposed by the developer and negotiated and accepted by the Government, consistent with the minimum requirements set forth in this section and with the overall objective of promoting the growth and development of U.S. private sector involvement in microgravity research and manufacturing.

The user requirements listed herein are considered to be minimums. Increases in certain specific areas may be desirable. It is the intent of the Government that the CDSF (1) offer additional hands-on microgravity science and research opportunities while in the attached-to-orbiter mode, (2) provide new long term automated materials processing and production opportunities while in the free flyer mode, and (3) be compatible with Space Station payload interfaces to assure that planned microgravity research facilities follow a logical progression of capability maturation in space. This approach also assures the maximum utilization flexibility of microgravity space hardware.

3.1 Volume/Weight

The CDSF shall be configured to provide a pressurizable volume, including all equipment and facilities required to activate the CDSF, which is deployable from a single launch by a launch service of the developer's choice, and capable of operations in both an attached-to-orbiter crew-operated mode and a free-flyer mode cycle. Weight and volume accommodations of the CDSF experiment payload should be consistent with the CDSF being operational on the first launch. The CDSF shall provide a minimum of 300 cubic feet of free volume within CDSF furnished racks for mounting Government and commercially furnished experiment equipment. Power and cooling shall be provided to this equipment volume. This volume does not include space required to store ancillary experiment equipment. (The mass of user equipment which can be mounted in the CDSF experiment equipment racks is also an important consideration.) Provisions for stowage of STS crew expendables should be considered within CDSF to support extended duration missions.

3.2 Environmental Control

When attached to the orbiter, the CDSF shall preserve a crew-habitable, "shirtsleeve environment" for periods up to 25 days duration with an extended duration Orbiter capability when available. In the free-flyer mode of operation, the developer shall provide and maintain a nominal sea-level atmospheric pressure in the CDSF module such that equipment (computers, furnaces, controllers, etc.) does not have to be designed to operate at reduced pressure, and cooling of equipment is facilitated. This requirement does not extend to providing an atmosphere capable of supporting human or animal life.

3.3 Crew Work Area

The crew work area of the CDSF shall be designed to accommodate, when attached to the orbiter, a minimum of 2 crewmembers working simultaneously in a shirtsleeve environment with foot and hand-holds available in appropriate locations.

3.4 Experiment Mechanical Interface Arrangement

The CDSF shall provide accommodations for standard user racks. User accommodation racks shall be designed for apparatus weighing a minimum of 25 pounds per cubic foot when integrated and will accommodate as a minimum existing Spacelab experiment hardware having a width of 17.425 inches and a depth of 29.094 inches. This will assure effective use of the current inventory of Spacelab-compatible experiment hardware and enable use of the CDSF for Research, Development, Test and Evaluation (RDT&E) of programmed experiment hardware anticipated as part of the evolution to the Space Station era.

3.5 Power

The CDSF power system will supply sufficient power to support the full requirements of the CDSF subsystems and user systems. The CDSF shall provide average power of at least 7 kilowatts to user systems. User experiments require both DC and AC power. All user locations will require ready access to power (and associated heat rejection); however, three locations shall be planned to accommodate "total power available" usage on a timelined basis. Offerors should recognize that material research/processing normally requires large amounts of power and related heat rejection. If solar arrays are used for power generation, the solar arrays will be required to track the sun in the attached-to-orbiter mode.

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3.6 Heat Rejection

The CDSF shall provide adequate heat rejection capability to users at experiment mounting locations.

3.7 Venting (to space vacuums)

Venting provisions will be provided at appropriate experiment locations.

3.8 Command and Data Management

The CDSF shall provide a C&DM system that is capable of performing the following functions:

a. Provide communications through the NASA Tracking and Data Relay Satellite System (TDRSS), or alternate system, at data rates of at least 16K bps, shared among facility housekeeping and user equipment. Data storage and retrieval capability shall be provided for those periods when direct communications through TDRSS or alternate system is not possible. A command uplink of a minimum of 1 Kbps is required.

If the CDSF developer elects to use the TDRSS during the free flyer mode, it shall enter into a Memorandum Of Agreement (MOA) with the NASA Associate Administrator for Space Operations for the reimbursable utilization of NASA's Space Network in accordance with the Use and Reimbursement Policy as published in the Federal Register under Title 14, Chapter V, Part 1215 48 Fed. Reg., 9845-9849 (initial issue March 9, 1983 with yearly updates for service rates). The process and procedures for arranging support from the Office of Space Operations for any of its services or resources will be in accordance with NASA Management Instruction (NMI) 8430.1B, effective May 26, 1987. Further, communications with TDRSS are authorized only within the 2285-2290 MHz range and must be consistent with standing U.S. National Radio Communications Law (Communications Act of 1934 as amended).

b. Individual CDSF subsystems must be reconfigurable from the ground to support individual experiment needs (e.g., vacuum venting, power switching, coolant flow.)

3.9 Microgravity Environment

In the free flyer mode, the CDSF shall maintain a microgravity environment of 1.0×10^{-6}g or better (for frequencies below 0.1 Hz) at the center of gravity, which shall be within the pressurized volume and available for experimental use.

Transient accelerations also need to be minimized for many processes. The low acceleration levels specified need to be maintainable for periods of up to 30 days while in the free flyer mode throughout the term of the lease.

3.10 Operability/Accessibility/Maintainability

The CDSF shall be designed to support microgravity research and manufacturing for both crew-operated and automated operations on-orbit.

Maximum on-orbit accessibility will be provided by the CDSF to accommodate both scheduled and unscheduled maintenance of user equipment and CDSF subsystems.

Capability for servicing CDSF subsystems shall be provided and the developer shall recommend the level of serviceable components.

Reasonable provisions shall be made for replacement of user parts, materials and/or serviceable components. Replacement of complete user systems shall be accommodated at the rack level while in the attached mode.

4.0 RESPONSIBILITIES

4.1 Required Coordination

4.1.1 The developer will coordinate with NASA who will perform those activities necessary to integrate the CDSF into the STS as defined in the standard NSTS payload integration process, reference NSTS 07700 Volume XIV, Space Shuttle Payload System Accommodations. Items which are not considered standard integration will be identified as NSTS Optional Services.

4.1.2 The developer will coordinate with NASA who will perform, on a mission basis, the integrated flight design from lift-off through initial deployment (when STS is utilized) and rendezvous for subsequent flights.

4.1.3 NASA will provide a cadre of Mission Specialists who will be trained by the developer on CDSF operations, maintenance and experiment operations to perform all crew-operated on-orbit CDSF operations. The developer will coordinate the CDSF crew requirements with NASA on a per mission basis. In addition, where experiment-unique requirements can be demonstrated, and subject to the approval of the NASA Administrator, either the Government or developer may elect to identify candidate Payload Specialists to conduct/operate Government or commercially furnished experiments on-orbit. The training of Mission Specialists and any Payload Specialists will be provided by the developer (for training on all CDSF operations, including the integrated experiment payload) and by NASA (for STS training required for any Payload Specialist).

4.1.4 All the above coordination will be implemented by the CDSF developer through an appropriate Launch Services Agreement.

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4.2 CDSF Developer

4.2.1 CDSF Development

4.2.1.1 The developer is responsible for the design, development, test, performance and safety of the CDSF carrier, ASE, and GSE. The developer is responsible for performing those functions necessary to insure the integration of the CDSF and any resupply carriers into the STS, when used for launch/recovery. The NSTS standard integration process and standard integration documentation will be utilized to integrate the facility and any resupply carriers into the STS, when used for launch/recovery. The developer will be responsible for providing the deliverables and accomplishing those activities as documented and negotiated in the Payload Integration Plan (PIP) to be negotiated between the NSTS and the CDSF developer. Specific items identified herein are highlighted to identify some items to be considered by the developer and to be negotiated under a separate Launch Services Agreement.

4.2.1.1.1 The developer is responsible for conducting reviews of the CDSF during the design and development process. During this process the Government will be provided an opportunity to submit Review Item Discrepancy (RIDs) pertaining to the STS/CDSF interfaces and STS/CDSF operations. NASA and other agency participation in these reviews does not constitute approval of the design nor certification as to its reliability.

4.2.1.1.2 The developer is responsible for the development and verification of CDSF operating procedures and malfunction procedures.

4.2.1.1.3 The developer is responsible for the safety certification of the facility in accordance with the NSTS safety process.

4.2.1.1.4 The developer shall obtain and provide training aids. Typical training aids to support crew-operated on-orbit operations are as follows:

- Visual model and functional math model of the CDSF to be used in the Shuttle Mission Simulator. Required for complex payloads and normally purchased through NSTS.

- Dynamic functional math model of the CDSF for use in the Shuttle Engineering Simulator for proximity operations procedure development. Normally purchased through NSTS.

- One g mockup of the CDSF with mockup of panels and racks for technique and procedure development for use by crew personnel at JSC.

- A neutrally buoyant (water) mockup of the CDSF for use in the Weightless Environment Training Facility (WETF). Needed only if Extra Vehicular Activity (EVA) is required.

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° A neutrally buoyant (air) mockup of the CDSF for use in the manipulator development facility. Needed only if Remote Manipulator System (RMS) is utilized.

° A high fidelity mockup of CDSF systems, subsystems, experiments, etc., that can be used for procedure validation and detail training of the Mission Specialist for on-orbit operations.

4.2.2 Mission Development

4.2.2.1 The developer is responsible for establishment of a total mission complement which includes Government, government-sponsored, and commercial experiments and for the integration of the facility, experiments, equipment, etc., for a particular mission. Responsibilities, data, supporting hardware, etc., will be as documented in a PIP for each mission.

4.2.2.2 The developer is responsible for the safety certification of the facility, and the total integrated configuration to be flown on a particular mission. (The individual Government experiments delivered to the developer will include appropriate safety certifications provided by NASA.)

4.2.2.3 The developer is responsible for the generation of the operating procedures, malfunction procedures and an integrated time line for crew-operated on-orbit operations.

4.2.2.4 The developer is responsible for the free flyer operations and flight control activities. This includes (as a minimum):

a. On-orbit CDSF systems and experiment operation, control, safing and maintenance.

b. Mission planning and execution.

c. All CDSF developer control room services/facilities activity and support.

d. Support of the scientific and industrial communities for command and data activity.

4.2.2.5 The developer will support Joint Integrated Simulations (JISs) conducted by the NASA to exercise joint operating procedures and payload malfunction/contingency operations and planning. The CDSF developer will support these simulations by providing (at a location selected by the developer) a flight configured control room and flight control room operators. The CDSF developer will also support the JISs by providing management support personnel in the Mission Control Center at JSC.

4.2.2.6 The developer will be responsible for the training of the NASA Mission Specialists and any NASA approved Payload Specialists in the operation of the CDSF and its experiments for all crew-operated on-orbit operations.

4.2.2.7 The developer is responsible for the definition and implementation of all documentation required for payload equipment development and integration. The developer is also responsible for the definition and implementation of all integrated mission documentation other than that described in paragraph 4.3.1 and shall include a delineation of responsibilities among the experiment equipment developers and the CDSF integrator.

4.3 Integration Documentation

4.3.1 The primary documentation to ensure proper integration of the CDSF into STS will consist of the Payload Integration Plan (PIP), the PIP annexes, and appropriate Interface Control Documents (ICDs) for the facility and for each mission.

The PIP, PIP annexes, unique ICD (or ICD addendum), and associated changes will be jointly approved by the NASA and the CDSF developer, except as otherwise stated in the Launch Services Agreement. Configuration control will be initiated upon signature approval. The NASA JSC will maintain configuration control of the cited documentation in accordance with Mission Integration Control Board Configuration Management Procedures, NSTS 18468, with the exception of the Launch Site Support Plan Annex, which will be maintained by the KSC in accordance with Instructions for KSC CP Configuration Control Board Operations, KSC K-CM-04.2.

4.3.2 For initial launch on any vehicle other than the STS, provision for integration documentation shall be made through an appropriate launch services agreement.

5.0 CDSF-to-STS Interface Requirements

The NSTS mechanical, electrical, avionics, and environmental policies and interfaces are contained in the Shuttle/Payload Standard Integration Plan for Deployable-Type Payloads, NSTS 21000-SIP-DEP, current issue and Space Shuttle System Payload Accommodations, NSTS 07700, Volume XIV, including Attachment 1 (ICD-2-19001) and Appendices 1-10, current issues.

The interface documentation between the CDSF and STS will be developed by NSTS utilizing the Shuttle/Payload Interface Definition Document for Standard Accommodations, JSC 21000-IDD-STS, current issue.

The CDSF will be capable of docking on-orbit with the Orbiter for the purposes of logistics and crew transfer in a pressurized shirt-sleeve environment. The interface between the CDSF and the NSTS will occur at an interfacing plane centered at Xo 604.5, Zo 364.28, and rotated 15 degrees, as shown on Figure 1.

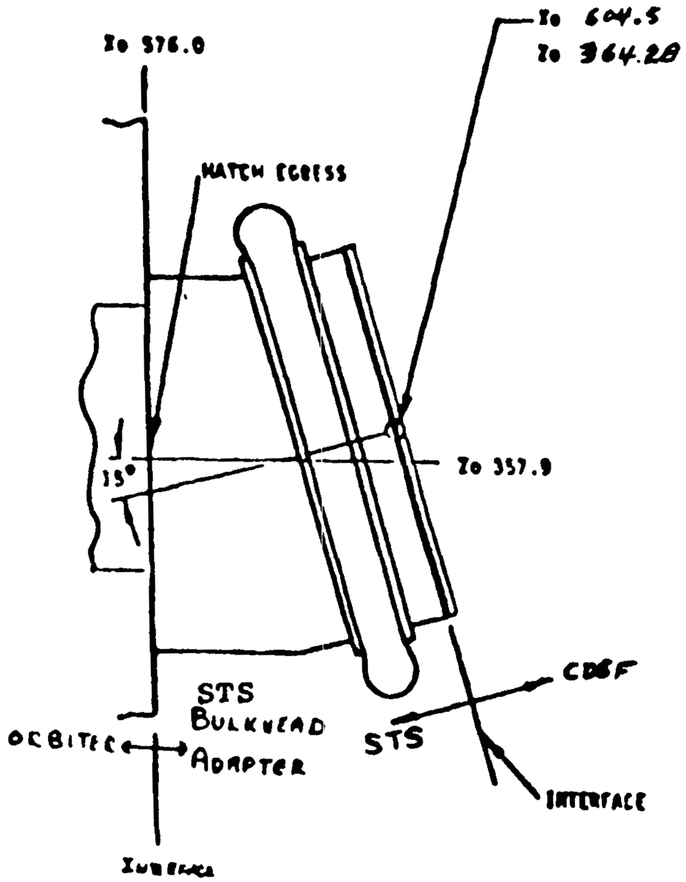

FIGURE 1

The NSTS side of the interface will be an NSTS-provided bulkhead adapter which will provide all active functions for establishing the pressure-tight interface with the CDSF side of the interface. The CDSF contractor will define the CDSF side of the interface. The CDSF-provided interface may be of such design as to be either (1) permanently attached to the CDSF, or (2) resident in the Orbiter for launch and landing for each flight. The contractor will bear launch costs and design and development costs, however, for all hardware aft of the Xo = 604.5 interface which is launched and/or recovered using the Orbiter. Additional specific requirements for the CDSF-to-NSTS interface will be defined in the Interface Control Document (ICD). Where needed, the contractor may include in the CDSF-to-NSTS interface concept utilization of the longeron and keel attachment points as defined in ICD-A-19001 for mechanical/structural attachment.

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The applicable documents to aid in the design of the CDSF to STS capabilities are provided in Section 8.0.

6.0 OPERATIONS

6.1 Mission Operations

6.1.1 Orbital Requirements - Deployment: Normal CDSF deployment will be from a near-circular orbit of 160 N.M. with an inclination of 28.45 plus or minus 0.1 degree (STS standard deployment orbit for shared flights).

6.1.2 Altitude - Altitude is constrained only by the Standard NSTS Servicing altitude of 174 n. mi.

6.1.3 Right Ascension of Ascending Node (RAAN): No RAAN constraints exist for the initial CDSF deployment. The RAAN value on subsequent missions is a function of the initial launch date and launch time, the carrier drag/reboost profile, and the STS planned revisit date. The developer shall specify two predicted delta-RAAN profiles covering the period between revisits. These profiles shall describe a predicted range of variation in RAAN from the payloads RAAN at the deployment or previous servicing mission. The two profiles shall correspond to the maximum and minimum operating altitudes of the payload. The difference in these profiles shall be at least 0.2 degrees of RAAN per day throughout the period described. For revisit missions the CDSF will achieve a RAAN value specified by the NSTS plus or minus 1.0 degree.

6.1.4 Control Parameters - CDSF design planning shall be within the NSTS capabilities as depicted in Figure 2 when the STS is to be used for launch.

6.2 Flight Operations

6.2.1 The launch interval requirement between missions shall not be less than 4 months and the CDSF shall be compatible with at least one missed revisit opportunity during a period of peak solar cycle activity.

6.2.2 Once in the correct operational orbit, the CDSF shall be capable of maintaining at least a 3-year orbital life without any servicing by the STS and be capable of supporting a subsequent STS revisit. The developer is responsible for safe recovery, re-entry, or disposal of the CDSF at the end of the lease or operational life, whichever is later.

6.2.3 The CDSF must be compatible with the Orbiter fleet including the Extended Duration Orbiter (when available) having a stay time of up to 25 days. The flexibility of CDSF should be exploited to operate in the attached, crew-operated mode, especially in connection with the Extended Duration Orbiter.

FIGURE 2

PAYLOAD LANDING WEIGHT CAPABILITY	33,121 LB.
PAYLOAD CAPABILITY (BASED ON A 28.5 DEGREE INCLINATION, AND 220 NM ORBIT)	31,630 LB.

- CAPABILITY EQUATES TO PAYLOAD PLUS ATTACH HARDWARE
- SUBTRACT (OR ADD) APPROXIMATELY 100 LB/NM FOR INCREASED (OR DECREASED) ALTITUDES
- CAPABILITY SHOWN IS FOR ALL ORBITERS
- EDO CAPABILITY IS NOT INCLUDED

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6.3 Ground Operations

6.3.1 All STS payload integration operations and testing at the launch site are scheduled and controlled by KSC launch site personnel.

6.3.2 The CDSF developer is responsible for the performance of all launch site payload unique operations and will provide personnel and GSE to conduct these operations.

6.3.3 The CDSF developer will support the Orbiter interface verification and launch process. Procedure inputs will be provided in accordance with the KSC procedure development schedules.

6.3.4 The CDSF developer is responsible for assuring that the CDSF and the GSE are safe and is responsible for reporting any change in payload safety status.

6.3.5 The CDSF developer supplied GSE to be used at KSC and the CDSF launch processing requirements will be compatible with existing facility resources and capabilities, or needed changes will be defined and funded by CDSF developer.

7.0 SAFETY

The CDSF developer is responsible for assuring that the CDSF, its experiment payloads, the ASE, and the GSE (including interfaces and operations) are safe. The CDSF, ASE, and GSE design and operations must comply with the safety requirements defined herein. Payload compliance with the safety requirements is assessed by the NSTS through four phases each of flight and ground safety reviews and safety certification. Successful completion of these safety reviews and of the safety certifications will result in the approval by the NSTS for ground processing and flight.

7.1 CDSF Design and Flight Operations Requirements - The CDSF and ASE design (including interfaces and operations) will comply with the requirements of NHB 1700.7B, Safety Policy and Requirements for Payloads Using the Space Transportation System. The CDSF and ASE shall meet these requirements at the launch/landing sites and during flight operations, orbital operations, and ferry flights. Meteoroid and debris shield design shall be in accordance with Section 7 of JSC 30425, Space Station Program Natural Environment Definition for Design.

7.2 GSE Design and Ground Operations Requirements - The CDSF, ASE, and GSE design (including interfaces and operations) will comply with the requirements of NHB 1700.7B and KHB 1700.7, Space Transportation System Payload Ground Safety Handbook, for launch site processing and post-landing operations including abort, contingency, and emergency landings.

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7.3 Safety and Review Requirements - The implementation of the safety requirements of NHB 1700.7B and KHB 1700.7 will be accomplished by NSTS 13830, Implementation Procedure for NSTS Payloads System Safety Requirements. The safety documentation will be provided by the CDSF developer to the appropriate NASA organization for each safety review. The safety review meeting will be scheduled approximately 45 days after the receipt of an acceptable data submittal.

8.0 MAJOR MILESTONES

8.1 Development: In order to assure compatibility of the CDSF design with the STS, the following major milestones must be met:

- PIP baselined - Not later than L-42 months.

- NSTS to CDSF ICDs baselined - L-36 months.

- CDSF Phase III Safety Review Successful Completion - Process must be completed prior to beginning of Experiment Physical Integration.

8.2 Mission Milestones - Milestones will be determined by the CDSF developer to be compatible with the NSTS Flight Schedule Template.

9.0 APPLICABLE DOCUMENTS FOR NSTS (Latest issue unless otherwise stated)

1. NSTS 21000-SIP-DEP: Shuttle/Payload Standard Integration Plan for Deployable-Type Payloads, Rev. J-1 dated 1/2/88

2. NSTS 21000-A01: Data Requirements for the Payload Data Package Annex, Rev. E dated 9/87

3. NSTS 21000-A02: Data Requirements for the Flight Planning Annex, Rev. C dated 5/87

4. NSTS 21000-A03: Data Requirements for the Flight Operations Support Annex, Rev. C dated 9/87

5. NSTS 21000-A04: Data Requirements for the Orbiter Command and Data Annex, Rev. F dated 5/87

6. NSTS 21000-A05: Data Requirements for POCC Annex, dated 7/87

7. NSTS 21000-A06: Data Requirements for the Crew Compartment Annex, Rev. C-2 dated 7/24/86

8. NSTS 21000-A07: Training Annex Data Requirements, Rev. E dated 10/87

9. K STSM 11.0: Horizontal Payload Boilerplate/Launch Site Support Plan (PIP Annex 8), dated 2/80

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9A. K DPM XX.X: Launch Site Support Plan for CDSF (PIP Annex 8), dated 8/81

10. NSTS 21000-A09: Payload Interface Verification Requirements, DRAFT Rev. A-1 dated 11/23/82

11. NSTS 21000-A11: Data Requirements for the Extravehicular Activity Annex, Rev. B-2 dated 10/9/87

12. NSTS 07700 Volume XIV: Space Shuttle System Payload Accommodations, Rev. J dated 9/24/87

13. NSTS 07700 Volume XIV, Appendix 1: System Description and Design Data - Contamination Environment, dated 2/17/88

14. NSTS 07700, Volume XIV, Appendix 2: System Description and Design Data - Thermal, dated 1/14/88

15. NSTS 07700, Volume XIV, Appendix 3: System Description and Design Data - Electrical Power and Avionics, Rev. J dated 11/10/87

16. NSTS 07700, Volume XIV, Appendix 4: System Description and Design Data - Structures and Mechanics, Rev. J dated 11/17/87

17. NSTS 07700, Volume XIV, Appendix 5: System Description and Design Data - Ground Operations, Rev. J dated 3/4/87

18. NSTS 07700, Volume XIV, Appendix 6: System Description and Design Data - Mission Planning and Flight Design, ROUGH DRAFT dated 2/29/88

19. NSTS 07700, Volume XIV, Appendix 7: System Description and Design Data - Extravehicular Activities, Rev. J dated 3/4/87

20. NSTS 07700, Volume XIV, Appendix 8: System Description and Design Data - Payload Deployment and Retrieval System, dated 7/24/87

21. NSTS 07700, Volume XIV, Appendix 9: System Description and Design Data - Intravehicular Activities, DRAFT PRELIMINARY OUTLINE attached to NASA-STD-3000, Volume V dated 3/7/88

22. NSTS 07700, Volume XIV, Appendix 10: System Description and Design Data - Integration Hardware, ROUGH DRAFT dated 2/29/88

23. NSTS 07700, Volume XIV, Attachment 1, ICD 2-19001: Shuttle Orbiter/Cargo Standard Interfaces, Rev. J., dated 3/88

24. NSTS 21000-IDD-STD: Shuttle/Payload Interface Definition Document for Standard Accommodations, dated 11/85

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25. NHB 1700.7B: Safety Policy and Requirements for Payloads Using the Space Transportation System (STS), DRAFT dated 2/2/88

26. NSTS 13830: Implementation Procedure for STS Payloads System Safety Requirements, DRAFT dated 1/25/88

27. NSTS 14046: Payload Verification Requirements, PRELIMINARY DRAFT dated 2/29/88

28. JSC 19943: Command Guidelines for STS Customers, dated 6/1/85

29. JSFC 11802: STS Reimbursement Guide, dated 5/80

30. ASME 8: ASME Boiler and Pressure Vessel Code Section 8, Division 1, updated through Winter 1986

31. MIL STD 1522A: Standard General Requirements for Safe Design and Operation of Pressurized Missile and Space Systems, dated 5/28/84

32. JSC 20793: Manned Space Vehicle Battery Safety Handbook, dated 9/85

33. K STSM 14.1: KSC Launch Site Accommodations Handbook for STS Payloads, Rev. B dated 1/83

34. NSS HP 1740.1: NASA Aerospace Pressure Vessel Safety Standard, dated 2/22/74

35. NSTS 21063: POCC Capabilities Document, dated 6/87

36. KHB 1700.7: STS Payload Ground Safety Handbook, Rev. A dated 11/30/84

37. JSC 18468: Mission Integration Control Board Configuration Management Procedures, Rev. A dated 7/85

38. NHB 8060.1: Flammability, Odor and Offgassing Requirements and Test Procedures for Materials in Environments that Support Combustion, dated 9/81

39. KSC K-CM-04.2: Instructions for KSC CP Configuration Control Board Operations, dated 11/20/79

10.0. OTHER APPLICABLE DOCUMENTS

1. Tracking and Data Relay Satellite System (TDRSS); Use and Reimbursement Policy for Non-U.S. Government Users (14 CFR Part 1215, Subpart 1)

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2. NASA Management Instruction (NMI) 8430.1B entitled, "Tracking and Data Systems Support For Unmanned Space Projects And For Suborbital and Aeronautical Flight Projects," effective May 26, 1987.

3. JSC 30425: Space Station Program Natural Environment Definition for Design - Dated 1/15/87

11.0. REFERENCE DOCUMENTS (For information and guidance only)

1. Payload Integration Plan, National Space Transportation System and Industrial Space Facility, dated January 20, 1988

2. Space Station/Orbiter Docking Interface Study, dated Nov~~ember 19,~~ 1987

3. Microgravity and Materials Processing Facility Study (MMPF), Requirements and Analysis of Commercial Operations (RACO), Preliminary Data Release (Contract NAS8-36122) dated March 3, 1988 + 28th March

4. Toxicological Support Requirements for the Shuttle Transportation System, dated March 18, 1983

5. Space Shuttle Radiation Instrumentation Return to Flight Design Requirements/Certification Review Document, dated February 1988

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APPENDIX A

CDSF MISSION

TYPICAL SCENARIO

Described below is a typical CDSF development/mission operations scenario with associated Government and CDSF developer responsibilities. For a baseline case the scenario assumes the CDSF is not only compatible with but actually will use the STS for launch as well as on-orbit servicing. The CDSF developer will work directly with the NSTS under the terms of a mutually agreed upon Launch Services Agreement (LSA).

I. Pre-Launch Activities

A. Development and Experiment Integration - The CDSF will be designed, fabricated, tested, experiments integrated, and the fully integrated CDSF tested in the CDSF developer's facilities. Government and commercial experiments will be designed and built to meet the CDSF specified interface and safety requirements, consistent with NASA safety requirements. (The Government will have no responsibility for non-Government furnished experiments.) NASA will deliver the Government experiments to the CDSF integration facility on a CDSF developer's specified date. The CDSF developer will integrate all experiments in the CDSF and should strive to accomplish the experiment integration and checkout cycle in the shortest time practical. It will be the CDSF developer's responsibility to get the fully integrated CDSF ready and certified for flight by the NSTS. This will be accomplished while meeting a standard set of NSTS schedule milestones often referred to as the NSTS payload integration template. Government lease payments will begin when the CDSF developer has provided approved, fully integrated, flightworthy hardware ready for integration into the Shuttle Orbiter. The fully integrated CDSF will be delivered by the CDSF developer to NASA at KSC. NASA will be responsible for final processing of the CDSF into the Orbiter and for launch. CDSF personnel will support these activities as required including support to NASA's control centers at Kennedy Space Center (KSC) (launch) and Johnson Space Center (JSC) (mission).

B. Training

Crew and ground personnel training will proceed in parallel with the development and integration process. Crew training at the experiment level will evolve from a stand-alone mode in the laboratory environment to a fully integrated one using the CDSF high fidelity simulator. Finally, the CDSF training facility with a mission unique complement of experiments, or simulated experiments, will be incorporated as an active element in joint integrated simulations with the STS, the Mission Control Center and the CDSF Control Center.

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APPENDIX A

II. Post-Launch Activities

A. On-orbit, Crew-Operated, Experiment Operations - The CDSF will provide a crew-operated shirtsleeve environment mode on-orbit while attached to a Shuttle Orbiter for periods up to 25 days when extended duration orbiter capabilities are available. Mission communications during this period will be via the TDRSS, although additional communication links are not precluded if needed for CDSF purposes.

B. Deployment, Free Flying and Servicing - The NASA will be responsible for deployment of the CDSF from the Orbiter. During Orbiter proximity operations, control will be from the Mission Control Center at JSC and will be the responsibility of NASA. All other free flying operations are the responsibility of the CDSF developer and CDSF control will be provided from a CDSF developer provided facility. The CDSF lessor will provide control room facilities to permit Government and commercial experimenters direct access to experiment data and required command functions during all mission phases involving experiment operations. (This includes experiment checkout and testing, on-orbit crew operations, and free flyer operations involving experiment operations.) The CDSF lessor may elect to use a communication system other than TDRSS during the free flyer mode. Use of the TDRSS services during the free flyer phase would require an agreement with NASA's Office of Space Operations separate from the NSTS Launch Services Agreement. Experiment samples and other data and/or articles will be removed from the CDSF in an Intervehicular Activity (IVA) mode. Experiments will be changed out as required and any required servicing or repairs to the CDSF accomplished. The CDSF will provide and have certified by the NSTS as flightworthy, all CDSF furnished equipment and experiments required for servicing visits which will occur no more frequently than four months.

Other than on-orbit services within the terms of the lease, services related to Government experiments subsequent to the initial payload complement deploy and recovery are considered an Optional CDSF Services not included in the base lease price.

C. Return, Reentry or Disposal - After completion of useful life, the CDSF will be returned to the Orbiter for return to Earth. Alternatives would be to design the CDSF for safe reentry or disposal at high altitude, so as not to create a hazard on reentry or a debris problem in low earth orbit. These alternatives would not be desirable unless the useful life of the experiment payload in the CDSF had also been expended.

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SECTION K

REPRESENTATIONS, CERTIFICATIONS,

AND OTHER STATEMENTS OF OFFERORS

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SECTION K

REPRESENTATIONS, CERTIFICATIONS, AND OTHER STATEMENTS OF OFFERORS

Certain representations and certifications must be made by the offeror and must be filled in as appropriate. The signature of the offeror in Block 17 of Standard Form 33 (which is the face page of this solicitation) constitutes the making of the applicable representations and certifications. Award of any contract to the offeror shall be considered to have incorporated the following applicable representations and certifications by reference in accordance with FAR 15.406(1)(b).

K-1
52.203-4 CONTINGENT FEE REPRESENTATION AND AGREEMENT (APR 1984)

(a) Representation. The offeror represents that, except for full-time bona fide employees working solely for the offeror, the offeror - [Note: The offeror must check the appropriate boxes. For interpretation of the representation, including the term "bona fide employee," see Subpart 3.4 of the Federal Acquisition Regulation.]

(1) ____ has, ____ has not employed or retained any person or company to solicit or obtain this contract; and

(2) ____ has, ____ has not paid or agreed to pay to any person or company employed or retained to solicit or obtain this contract any commission, percentage, brokerage, or other fee contingent upon or resulting from the award of this contract.

(b) Agreement. The offeror agrees to provide information relating to the above Representation as requested by the Contracting Officer and, when subparagraph (a)(1) or (a)(2) is answered affirmatively, to promptly submit to the Contracting Officer -

(1) A completed Standard Form 119, Statement of Contingent or Other Fees, (SF 119); or

(2) A signed statement indicating that the SF 119 was previously submitted to the same contracting office, including the date and applicable solicitation or contract number, and representing that the prior SF 119 applies to this offer or quotation.

(End of Provision)

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K-2
52.215-6 TYPE OF BUSINESS ORGANIZATION (JUL 1987)

The offeror or quoter, by checking the applicable box, represents that --
(a) It operates as / / a corporation incorporated under the laws of the State of ________________, / / an individual, / / a partnership, / / a nonprofit organization, or / / a joint venture; or
(b) If the offeror or quoter is a foreign entity, it operates as / / an individual, / / a partnership, / / a nonprofit organization, / / a joint venture, or / / a corporation, registered for business in

____________________.
country

(End of Provision)

K-3
52.215-11 AUTHORIZED NEGOTIATORS (APR 1984)

The offeror or quoter represents that the following persons are authorized to negotiate on its behalf with the Government in connection with this request for proposals or quotations: [List names, titles, and telephone numbers of the authorized negotiators.]

____

____

____

(End of Provision)

K-4
52.215-20 PLACE OF PERFORMANCE (APR 1984)

(a) The offeror or quoter, in the performance of any contract resulting from this solicitation, ____ intends, ____ does not intend (check applicable block) to use one or more plants or facilities located at a different address from the address of the offeror or quoter as indicated in this proposal or quotation.

(b) If the offeror or quoter checks "intends" in paragraph (a) above, it shall insert in the space provided below the required information:

Place of Performance (Street Address, City, County, State, Zip Code)	Name and Address of Owner and Operator of the Plant or Facility if Other than Offeror or Quoter
____________________	____________________
____________________	____________________
____________________	____________________

(End of Provision)

K-5
52.219-1 SMALL BUSINESS CONCERN REPRESENTATION (MAY 1986)

The offeror represents and certifies as part of its offer that it ____ is, ____ is not a small business concern and that ____ all, ____ not all supplies to be furnished will be manufactured or produced by a small business concern in the United States, its territories or possessions, Puerto Rico, or the Trust Territory of the Pacific Islands. "Small business concern," as used in this provision, means a concern, including its affiliates, that is independently owned and operated, not dominant in the field of operation in which it is bidding on Government contracts, and qualified as a small business under the size standards in this solicitation.

(End of Provision)

K-6
52.219-2 SMALL DISADVANTAGED BUSINESS CONCERN REPRESENTATION (APR 1984)

(a) Representation. The offeror represents that it ____ is, ____ is not a small disadvantaged business concern.

(b) Definitions.
"Asian-Indian American," as used in this provision, means a United States citizen whose origins are in India, Pakistan, or Bangladesh.

"Asian-Pacific American," as used in this provision, means a United States citizen whose origins are Japan, China, the Philippines, Vietnam, Korea, Samoa, Guam, the U.S. Trust Territory of the Pacific Islands, the Northern Mariana Islands, Laos, Cambodia, or Taiwan.

"Native American," as used in this provision, means American Indians, Eskimos, Aleuts, and native Hawaiians.

"Small business concern," as used in this provision, means a concern, including its affiliates, that is independently owned and operated, not dominant in the field of operation in which it is bidding on Government contracts, and qualified as a small business under the criteria and size standards in 13 CFR 121.

"Small disadvantaged business concern," as used in this provision, means a small business concern that (1) is at least 51 percent owned by one or more individuals who are both socially and economically disadvantaged, or a publicly owned business having at least 51 percent of its stock owned by one or more socially and economically disadvantaged individuals and (2) has its management and daily business controlled by one or more such individuals.

(c) Qualified groups. The offeror shall presume that socially and economically disadvantaged individuals include Black Americans, Hispanic Americans, Native Americans, Asian-Pacific Americans, Asian-Indian Americans, and other individuals found to be qualified by the SBA under 13 CFR 124.1.

(End of Provision)

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K-7
52.219-3 WOMEN-OWNED SMALL BUSINESS REPRESENTATION (APR 1984)

(a) Representation. The offeror represents that it ____ is, ____ is not a women-owned small business concern.

(b) Definitions.
"Small business concern," as used in this provision, means a concern, including its affiliates, that is independently owned and operated, not dominant in the field of operation in which it is bidding on Government contracts, and qualified as a small business under the criteria and size standards in 13 CFR 121.

"Women-owned," as used in this provision, means a small business that is at least 51 percent owned by a woman or women who are U.S. citizens and who also control and operate the business.

(End of Provision)

K-8
52.222-19 WALSH-HEALEY PUBLIC CONTRACTS ACT REPRESENTATION (APR 1984)

The offeror represents as a part of this offer that the offeror is ____ or is not ____ a regular dealer in, or is ____ or is not ____ a manufacturer of, the supplies offered.

(End of Provision)

K-9
52.222-21 CERTIFICATION OF NONSEGREGATED FACILITIES (APR 1984)

(a) "Segregated facilities," as used in this provision, means any waiting rooms, work areas, rest rooms and wash rooms, restaurants and other eating areas, time clocks, locker rooms and other storage or dressing areas, parking lots, drinking fountains, recreation or entertainment areas, transportation, and housing facilities provided for employees, that are segregated by explicit directive or are in fact segregated on the bases of race, color, religion, or national origin because of habit, local custom, or otherwise.

(b) By the submission of this offer, the offeror certifies that it does not and will not maintain or provide for its employees any segregated facilities at any of its establishments, and that it does not and will not permit its employees to perform their services at any location under its control where segregated facilities are maintained. The offeror agrees that a breach of this certification is a violation of the Equal Opportunity clause in the contract.

(c) The offeror further agrees that (except where it has obtained identical certifications from proposed subcontractors for specific time periods) it will -

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(1) Obtain identical certifications from proposed subcontractors before the award of subcontracts under which the subcontractor will be subject to the Equal Opportunity clause:

(2) Retain the certifications in the files; and

(3) Forward the following notice to the proposed subcontractors (except if the proposed subcontractors have submitted identical certifications for specific time periods):

NOTICE TO PROSPECTIVE
SUBCONTRACTORS OF REQUIREMENT
FOR CERTIFICATIONS OF
NONSEGREGATED FACILITIES

A Certification of Nonsegregated Facilities must be submitted before the award of a subcontract under which the subcontractor will be subject to the Equal Opportunity clause. The certification may be submitted either for each subcontract or for all subcontracts during a period (i.e., quarterly, semiannually, or annually).

NOTE: The penalty for making false statements in offers is prescribed in 18 U.S.C. 1001.

(End of Provision)

K-10
52.222-22 PREVIOUS CONTRACTS AND COMPLIANCE REPORTS (APR 1984)

The offeror represents that -

(a) It ____ has, ____ has not participated in a previous contract or subcontract subject either to the Equal Opportunity clause of this solicitation, the clause originally contained in Section 310 of Executive Order No. 10925, or the clause contained in Section 201 of Executive Order No. 11114;

(b) It ____ has, ____ has not, filed all required compliance reports; and

(c) Representations indicating submission of required compliance reports, signed by proposed subcontractors, will be obtained before subcontract awards.

(End of Provision)

K-11
52.222-25 AFFIRMATIVE ACTION COMPLIANCE (APR 1984)

The offeror represents that (a) it ____ has developed and has on file, ____ has not developed and does not have on file, at each establishment, affirmative action programs required by the rules and regulations of the

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Secretary of Labor (41 CFR 60-1 and 60-2), or (b) it ____ has not previously had contracts subject to the written affirmative action programs requirement of the rules and regulations of the Secretary of Labor.

(End of Provision)

K-12
52.245-90 REVIEW AND CORRECTION OF CONTRACTOR'S PROPERTY CONTROL SYSTEMS (JAN 1987) (Ref. NASA/FAR Supplement 18-45.104)

For this contract, it is expected that the Contractor will _____, will not _____ utilize Government Property.

If Government property is to be used in the performance of the resultant contract, the following information shall be furnished by the offeror:

A. Date of the last review by the Government of offeror's property control and accounting system:

____

B. Description of action(s) taken to correct any deficiencies found:

____

____

____

C. Has reviewed, understands, and can comply with all property management and accounting procedures in this solicitation, FAR Subpart 45.5, and NASA FAR Supplement Subparts 18-45.5, 18-45.70, and 18-45.71.

Yes _______ No _______

D. Costs associated with subparagraph C. above are included in the offeror's cost proposal.

Yes _______ No _______

(End of Provision)

K-13
18-52.203-70 CONTRACTS BETWEEN NASA AND FORMER NASA EMPLOYEES (APR 1984)

The offeror represents that he or she ____ is, or ____ is not, an individual who was employed by NASA during the past two (2) years, or a firm in which such former employee is a partner, principal officer, majority shareholder, or which is otherwise controlled or predominantly staffed by such former employees.

(End of Provision)

K-14

18-52.215-72 RESTRICTION ON USE AND DISCLOSURE OF PROPOSAL/QUOTATION INFORMATION (DATA) (DEC 1984)

It is NASA policy to use information contained in proposals and quotations for evaluation purposes only. While this policy does not require that the proposal or quotation bear a restrictive notice, offerors and quoters should, in order to maximize protection of trade secrets or other information that is commercial or financial and confidential or privileged, place the following notice on the title page of the proposal or quotation and specify the information, subject to the notice by inserting appropriate identification, such as page numbers, in the notice. In any event, information (data) contained in proposals and quotations will be protected to the extent permitted by law, but NASA assumes no liability for use and disclosure of information not made subject to the notice.

RESTRICTION ON USE AND DISCLOSURE OF PROPOSAL AND QUOTATION INFORMATION (DATA)

The information (data) contained in ______ (insert page numbers or other identification) of this proposal or quotation constitutes a trade secret and/or information that is commercial or financial and confidential or privileged. It is furnished to the Government in confidence with the understanding that it will not, without permission of the offeror, be used or disclosed for other than evaluation purposes; provided, however, that in the event a contract is awarded on the basis of this proposal or quotation the Government shall have the right to use and disclose this information (data) to the extent provided in the contract. This restriction does not limit the Government's right to use or disclose this information (data) if obtained from another source without restriction.

(End of Provision)

K-15

52.203-2 CERTIFICATE OF INDEPENDENT PRICE DETERMINATION (APR 1985)

(a) The offeror certifies that -

(1) The prices in this offer have been arrived at independently, without, for the purpose of restricting competition, any consultation, communication, or agreement with any other offeror or competitor relating to (i) those prices, (ii) the intention to submit an offer, or (iii) the methods or factors used to calculate the prices offered;

(2) The prices in this offer have not been and will not be knowingly disclosed by the offeror, directly or indirectly, to any other offeror or competitor before bid opening (in the case of a sealed bid solicitation) or contract award (in the case of a negotiated solicitation) unless otherwise required by law; and

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(3) No attempt has been made or will be made by the offeror to induce any other concern to submit or not to submit an offer for the purpose of restricting competition.

(b) Each signature on the offer is considered to be a certification by the signatory that the signatory -

(1) Is the person in the offeror's organization responsible for determining the prices being offered in this bid or proposal, and that the signatory has not participated and will not participate in any action contrary to subparagraphs (a)(1) through (a)(3) above; or

(2) (i) Has been authorized, in writing, to act as agent for the following principals in certifying that those principles have not participated, and will not participate in any action contrary to subparagraphs (a)(1) through (a)(3) above ______________________________ ______________________________ [Insert full name of person(s) in the offeror's organization responsible for determining the prices offered in this bid or proposal, and the title of his or her position in the offeror's organization];

(ii) As an authorized agent, does certify that the principals named in subdivision (b)(2)(i) above have not participated, and will not participate, in any action contrary to subparagraphs (a)(1) through (a)(3) above; and

(iii) As an agent, has not personally participated, and will not participate, in any action contrary to subparagraphs (a)(1) through (a)(3) above.

(c) If the offeror deletes or modifies subparagraph (a)(2) above, the offeror must furnish with its offer a signed statement setting forth in detail the circumstances of the disclosure.

(End of Provision)

K-16
52.220-1 PREFERENCE FOR LABOR SURPLUS AREA CONCERNS (APR 1984)

(a) This acquisition is not a set-aside for labor surplus area (LSA) concerns. However, the offeror's status as such a concern may affect (1) entitlement to award in case of tie offers or (2) offer evaluation in accordance with the Buy American Act clause of this solicitation. In order to determine whether the offeror is entitled to a preference under (1) or (2) above, the offeror must identify, below, the LSA in which the costs to be incurred on account of manufacturing or production (by the offeror or the first-tier subcontractors) amount to more than 50 percent of the contract price.

________________________ ________________________

________________________ ________________________

(b) Failure to identify the locations as specified above will preclude consideration of the offeror as an LSA concern. If the offeror is awarded a contract as an LSA concern and would not have otherwise qualified for award, the offeror shall perform the contract or cause the contract to be performed in accordance with the obligations of an LSA concern.

(End of Provision)

K-17
52.223-1 CLEAN AIR AND WATER CERTIFICATION (APR 1984)

The offeror certifies that -

(a) Any facility to be used in the performance of this proposed contract is ____, is not ____, listed on the Environmental Protection Agency List of Violating Facilities;

(b) The offeror will immediately notify the Contracting Officer, before award, of the receipt of any communication from the Administrator, or a designee, of the Environmental Protection Agency, indicating that any facility that the offeror proposes to use for the performance of the contract is under consideration to be listed on the EPA List of Violating Facilities; and

(c) The offeror will include a certification substantially the same as this certification, including this paragraph (c), in every nonexempt subcontract.

(End of Provision)

K-18
52.246-90 SPACE TRANSPORTATION SYSTEM (STS) PERSONNEL ACCESS CERTIFICATION (JAN 1987)

The offeror certifies that the performance of the work in this solicitation will _____, will not _____ involve personnel position requiring access to the STS vehicle or command capability through the Launch Processing System or the Mission Control Center.

(End of Provision)

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K-19
CONTRACTOR REPRESENTATION

Unless the Contractor expressly states otherwise in the Contractor's proposal, where performance requirements are expressly stated as part of the requirements of this solicitation, the Contractor, by responding, represents that in its opinion the system/item(s) proposed is capable of meeting those requirements.

(End of Provision)

K-20
DOMESTIC SOURCE CERTIFICATION

The offeror certifies that -

(a) It is a United States industry which means any corporation, partnership, joint venture, association, or other entity which is organized or existing under the laws of the United States or any state, and whose controlling interest is held by United States citizens or other entities whose controlling interest is held by United States citizens. "Controlling interest" means ownership of an amount of equity in such entity sufficient to direct management or to void transactions entered into by management. Ownership of at least fifty-one percent of equity creates a rebuttable presumption that such interest is controlling.

(b) All its major subcontractors are United States industries as defined above in paragraph (a). "Major subcontractor" means an entity who performs any effort for the prime contractor for a total monetary consideration of at least $500,000.

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SECTION L

SOLICITATION PROVISIONS, GENERAL INFORMATION,

AND INSTRUCTIONS FOR PROPOSAL PREPARATION

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SECTION L

SOLICITATION PROVISIONS, GENERAL INFORMATION, AND INSTRUCTIONS FOR PROPOSAL PREPARATION

Subsection L-I

Instructions, Conditions and Notices to Offeror

Subsection L-II

Instructions for Proposal Preparation

Subsection L-III

Specific Instructions for Proposal Preparation

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SUBSECTION L-I

INSTRUCTIONS, CONDITIONS AND NOTICES TO OFFEROR

The following Instructions, Conditions, and Notices are applicable to this Request for Proposal and must be adhered to.

L-1
52.212-7 NOTICE OF PRIORITY RATING FOR NATIONAL DEFENSE USE (MAY 1986)

Any contract awarded as a result of this solicitation will be a ____ DX rated order; _X_ DO rated order certified for national defense use under the Defense Priorities and Allocations System (DPAS) (15 CFR 350), and the Contractor will be required to follow all of the requirements of this regulation.

(End of Provision)

L-2
52.215-5 SOLICITATION DEFINITIONS (JUL 1987)

"Offer" means "proposal" in negotiation.
"Solicitation" means a request for proposals (RFP) or a request for quotations (RFQ) in negotiation.
"Government" means United States Government.
"Contractor" means "Lessor" and/or "CDSF Developer."

(End of Provision)

L-3
52.215-7 UNNECESSARILY ELABORATE PROPOSALS OR QUOTATIONS (APR 1984)

Unnecessarily elaborate brochures or other presentations beyond those sufficient to present a complete and effective response to this solicitation are not desired and may be construed as an indication of the offeror's or quoter's lack of cost consciousness. Elaborate art work, expensive paper and bindings, and expensive visual and other presentation aids are neither necessary nor wanted.

(End of Provision)

L-4
52.215-8 ACKNOWLEDGEMENT OF AMENDMENTS TO SOLICITATIONS (APR 1984)

Offerors shall acknowledge receipt of any amendment to this solicitation (a) by signing and returning the amendment; (b) by identifying the amendment number and date in the space provided for this purpose on the form for submitting an offer; or (c) by letter or telegram. The Government must receive the acknowledgement by the time specified for receipt of offers.

(End of Provision)

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L-5

52.215-9 SUBMISSION OF OFFERS (APR 1984)

(a) Offers and modifications thereof shall be submitted in sealed envelopes or packages (1) addressed to the office specified in the solicitation and (2) showing the time specified for receipt, the solicitation number, and the name and address of the offeror.

(b) Telegraphic offers will not be considered unless authorized by the solicitation; however, offers may be modified by written or telegraphic notice, if that notice is received by the time specified for receipt of offers.

(c) Item samples, if required, must be submitted within the time specified for receipt of offers. Unless otherwise specified in the solicitation, these samples shall be (1) submitted at no expense to the Government and (2) returned at the sender's request and expense, unless they are destroyed during preaward testing.

(End of Provision)

L-6

52.215-10 LATE SUBMISSIONS, MODIFICATIONS, AND WITHDRAWALS OF PROPOSALS (APR 1984)

(a) Any proposal received at the office designated in the solicitation after the exact time specified for receipt will not be considered unless it is received before award is made and it --

(1) Was sent by registered or certified mail not later than the fifth calendar day before the date specified for receipt of offers (e.g., an offer submitted in response to a solicitation requiring receipt of offers by the 20th of the month must have been mailed by the 15th);

(2) Was sent by mail (or telegram if authorized) and it is determined by the Government that the late receipt was due solely to mishandling by the Government after receipt at the Government installation; or

(3) Is the only proposal received.

(b) Any modification of a proposal or quotation, except a modification resulting from the Contracting Officer's request for "best and final" offer, is subject to the same conditions as in subparagraphs (a)(1) and (2) above.

(c) A modification resulting from the Contracting Officer's request for "best and final" offer received after the time and date specified in the request will not be considered unless received before award and the late receipt is due solely to mishandling by the Government after receipt at the Government installation.

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(d) The only acceptable evidence to establish the date of mailing of a late proposal or modification sent either by registered or certified mail is the U.S. or Canadian Postal Service postmark on the wrapper or on the original receipt from the U.S. or Canadian Postal Service. If neither postmark shows a legible date, the proposal, quotation, or modification shall be processed as if mailed late. "Postmark" means a printed, stamped, or otherwise placed impression (exclusive of a postage meter machine impression) that is readily identifiable without further action as having been supplied and affixed by employees of the U.S. or Canadian Postal Service on the date of mailing. Therefore, offerors or quoters should request the postal clerks to place a hand cancellation bull's-eye postmark on both the receipt and the envelope or wrapper.

(e) The only acceptable evidence to establish the time of receipt at the Government installation is the time/date stamp of that installation on the proposal wrapper or other documentary evidence of receipt maintained by the installation.

(f) Notwithstanding paragraph (a) above, a late modification of an otherwise successful proposal that makes its terms more favorable to the Government will be considered at any time it is received and may be accepted.

(g) Proposals may be withdrawn by written notice or telegram (including mailgram) received at any time before award. Proposals may be withdrawn in person by an offeror or an authorized representative, if the representative's identity is made known and the representative signs a receipt for the proposal before award.

(End of Provision)

L-7
52.215-13 PREPARATION OF OFFERS (APR 1984)

(a) Offerors are expected to examine the drawings, specifications, Schedule, and all instructions. Failure to do so will be at the offeror's risk.

(b) Each offeror shall furnish the information required by the solicitation. The offeror shall sign the offer and print or type its name on the Schedule and each continuation sheet on which it makes an entry. Erasures or other changes must be initialed by the person signing the offer. Offers signed by an agent shall be accompanied by evidence of that agent's authority, unless that evidence has been previously furnished to the issuing office.

(c) For each item offered, offerors shall (1) show the unit price/cost, including, unless otherwise specified, packaging, packing, and preservation and (2) enter the extended price/cost for the quantity of each item offered in the "Amount" column of the Schedule. In case of discrepancy between a unit price/cost and an extended price/cost, the unit price/cost will be presumed to be correct, subject, however, to correction to the same extent and in the same manner as any other mistake.

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(d) Offers for supplies or services other than those specified will not be considered unless authorized by the solicitation.

(e) Offerors must state a definite time for delivery of supplies or for performance of services, unless otherwise specified in the solicitation.

(f) Time, if stated as a number of days, will include Saturdays, Sundays, and holidays.

(End of Provision)

L-8
52.215-14 EXPLANATION TO PROSPECTIVE OFFERORS (APR 1984)

Any prospective offeror desiring an explanation or interpretation of the solicitation, drawings, specifications, etc., must request it in writing soon enough to allow a reply to reach all prospective offerors before the submission of their offers. Oral explanations or instructions given before the award of the contract will not be binding. Any information given to a prospective offeror concerning a solicitation will be furnished promptly to all other prospective offerors as an amendment of the solicitation, if that information is necessary in submitting offers or if the lack of it would be prejudicial to any other prospective offerors.

(End of Provision)

L-9
52.215-15 FAILURE TO SUBMIT OFFER (APR 1984)

Recipients of this solicitation not responding with an offer should not return this solicitation, unless it specifies otherwise. Instead, they should advise the issuing office by letter or postcard whether they want to receive future solicitations for similar requirements. If a recipient does not submit an offer and does not notify the issuing office that future solicitations are desired, the recipient's name may be removed from the applicable mailing list.

(End of Provision)

L-10
52.215-16 CONTRACT AWARD (APR 1985)

(a) The Government will award a contract resulting from this solicitation to the responsible offeror whose offer conforming to the solicitation will be most advantageous to the Government, cost or price and other factors, specified elsewhere in this solicitation, considered.

(b) The Government may (1) reject any or all offers if such action is in the public interest, (2) accept other than the lowest offer, and (3) waive informalities and minor irregularities in offers received.

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(c) The Government may award a contract on the basis of initial offers received, without discussions. Therefore, each initial offer should contain the offeror's best terms from a cost or price and technical standpoint.

(d) The Government may accept any item or group of items of an offer, unless the offeror qualifies the offer by specific limitations. Unless otherwise provided in the Schedule, offers may be submitted for quantities less than those specified. The Government reserves the right to make an award on any item for a quantity less than the quantity offered, at the unit cost or prices offered, unless the offeror specifies otherwise in the offer.

(e) A written award or acceptance of offer mailed or otherwise furnished to the successful offeror within the time for acceptance specified in the offer shall result in a binding contract without further action by either party. Before the offer's specified expiration time, the Government may accept an offer (or part of an offer, as provided in paragraph (d) above), whether or not there are negotiations after its receipt, unless a written notice of withdrawal is received before award. Negotiations conducted after receipt of an offer do not constitute a rejection or counteroffer by the Government.

(f) Neither financial data submitted with an offer, nor representations concerning facilities or financing, will form a part of the resulting contract. However, if the resulting contract contains a clause providing for price reduction for defective cost or pricing data, the contract price will be subject to reduction if cost or pricing data furnished is incomplete, inaccurate, or not current.

(End of Provision)

L-11
EXPENSES RELATED TO OFFEROR SUBMISSIONS

This solicitation does not commit the Government to pay any cost incurred in the submission of the offer/quotation or in making necessary studies or designs for the preparation thereof, nor to contract for service or supplies.

L-12
52.215-91 INSTRUCTIONS FOR EXECUTED SF 33 AND SECTIONS B THRU K (JAN 1987)

Blocks 12 through 18 of the SF 33 must be filled-in as appropriate and returned in the number specified below along with sections indicated. FAR 52.215-13 ("Preparation of Offers") requires any erasures or other changes be initialed by the person signing the offer. If award is not made on the SF 33, then award will be made by using SF 26 via a separate and subsequent transmittal for signature by the offeror.

_X_ One signed copy of SF 33 along with Section K.

____ Three original signed copies of SF 33 along with one (1) copy of Sections B thru K must be returned with your offer.

If additional separate volumes are required, the number and instructions for preparation will be contained in Section L-II of this solicitation.

(End of Provision)

L-13
52.215-93 COMMUNICATIONS REGARDING THIS SOLICITATION (APR 1987)

Any communications in reference to this solicitation shall cite the solicitation number and be directed to the following Government representative:

Name:	K.D. Sowell
Phone:	205-544-0360 (collect calls not accepted)
Address:	George C. Marshall Space Flight Center Attention: K.D. Sowell, Mail Code: AP32 Marshall Space Flight Center, AL 35812

QUESTIONS MUST BE PRESENTED IN WRITING and must be submitted to the above address within seven days of the RFP issue date in order that answers may be obtained and disseminated in a timely manner, since it is not expected that the proposal submission date can be extended.

L-14
52.215-95 OFFEROR ACCEPTANCE PERIOD (JAN 1987)

The offeror shall insert a period of not less than 180 calendar days in Block 12 of Standard Form 33 (face page of this solicitation).

(End of Provision)

L-15
52.215-96 PENALTY FOR MAKING FALSE STATEMENTS (JAN 1987)

PROPOSALS MUST SET FORTH FULL, ACCURATE, AND COMPLETE INFORMATION AS REQUIRED BY THE REQUEST FOR PROPOSAL (INCLUDING ATTACHMENTS). THE PENALTY FOR MAKING FALSE STATEMENTS IN PROPOSALS IS PRESCRIBED IN 18 U.S.C. 1001.

(End of Provision)

L-16
52.216-1 TYPE OF CONTRACT (APR 1984)

The Government contemplates award of a firm-fixed-price contract resulting from this solicitation.

(End of Provision)

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L-17
52.219-92 SIC CODE AND SMALL BUSINESS SIZE STANDARD (JAN 1987)

The standard industrial classification code for this procurement is 3761. The Small Business Administration Size Standard is 1000 employees, or $N/A in average annual sales or receipts for the preceding 3 years.

(End of Provision)

L-18
52.233-2 SERVICE OF PROTEST (JAN 1985)

Protests, as defined in Section 33.101 of the Federal Acquisition Regulation, shall be served on the Contracting Officer by obtaining written and dated acknowledgement of receipt from the address in Block 7 of Standard Form 33.

(End of Provision)

L-19
52.215-92 DISPOSITION OF OFFER (JAN 1987)

After a Contractor has been selected, unsuccessful offers will be disposed of as follows: one copy of each offer will be retained by the issuing office and the remainder will be destroyed. No destruction certificate will be furnished.

(End of Provision)

L-20--RESERVED

L-21
52.222-24 PREAWARD ON-SITE EQUAL OPPORTUNITY COMPLIANCE REVIEW (APR 1984)

An award in the amount of $1 million or more will not be made under this solicitation unless the offeror and each of its known first-tier subcontractors (to whom it intends to award a subcontract of $1 million or more) are found, on the basis of a compliance review, to be able to comply with the provisions of the Equal Opportunity clause of this solicitation.

(End of Provision)

L-22
52.222-90 LABOR INFORMATION (JAN 1987)

General Information regarding the requirements of the Walsh-Healey Public Contracts Act (41 U.S.C. 35-45), the Contract Work Standards Act (40 U.S.C. 327-330), and the Service Contract Act of 1965 (41 U.S.C. 351-357) may be obtained from the Department of Labor, Washington, DC 20210, or from any regional office of that agency. Requests for information should include the solicitation number, the name and address of the issuing agency, and a description of the supplies or services.

(End of Provision)

L-23
52.237-1 SITE VISIT (APR 1984)

Offerors or quoters are urged and expected to inspect the site where services are to be performed and to satisfy themselves regarding all general and local conditions that may affect the cost of contract performance, to the extent that the information is reasonably obtainable. In no event shall failure to inspect the site constitute grounds for a claim after contract award.

(End of Provision)

L-24
52.237-90 PRE-AWARD OPERATIONAL STATUS REVIEW (JAN 1987)

The Government reserves the right to visit an offeror's facility or to request the offeror to come to MSFC for the purpose of reviewing the status and applicability of management and/or technical systems proposed for planning, status, or control of work to be performed as part of this solicitation.

(End of Provision)

L-25
52.246-91 NOTICE TO OFFERORS: MISSION CRITICAL POSITIONS FOR THE SPACE TRANSPORTATION SYSTEM (JAN 1987)

The selected Contractors will comply with the provisions of NASA Management Instruction 8610.13.

(End of Provision)

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SUBSECTION L-II

GENERAL INSTRUCTIONS FOR PROPOSAL PREPARATION

L-II-1
GOVERNMENT FUNDING

Funding for the proposed lease is not currently available. The Administration intends to seek legislation which would provide advanced appropriations to become available when a fully integrated flightworthy facility is available for lease. It is the Administration's intention to seek, on an annual basis, additional appropriations to cover an appropriate level of Government liability in the event of termination for the convenience of the Government.

L-II-2
GENERAL

A. Each offeror shall furnish 25 sets of its proposal in two (2) volumes containing the following information:

Volume	Title	*Page Limitation
I	Business Proposals	125**
II	Technical Proposal	125**

*The page limitation excludes Section K, Representation/ Certifications and those items specified in Subsection L-III as being exempt.

**The 125 page limitation includes 25 pages for the discussion of the two Government annual funding scenarios of $80 million and $140 million (in 1988 dollars). The discussions shall be covered in a separate section of the Business and Technical proposals.

B. Data submitted in excess of the page limitations specified will not be considered and will be returned to the offeror. Information requested herein must be furnished fully and completely in compliance with instructions. The information requested and the manner of submittal are essential to permit prompt evaluation of all proposals on a fair and uniform basis. Proposals must be clearly responsive to the requirements of the RFP; accordingly, any proposal in which material or information requested is not furnished, or where indirect or incomplete answers or information are provided, may be considered not acceptable.

C. The proposal text must be printed in type not smaller than Pica on approximately 8-1/2" x 11" paper. The proposals should be stapled or bound. Illustrations and forms shall be legible and no larger than 11" x 17" foldouts, as appropriate for the subject matter.

D. Materials may not be incorporated by reference to circumvent the aforementioned page limitations.

E. The offeror's proposal and all supporting documentation shall be submitted in English.

L-II-3
CONTRACT SCHEDULE ARTICLES

Included in this RFP are the Contract Schedule Articles and contract clauses proposed for inclusion into any resultant contract. Your proposal shall include a definite commitment of acceptance to the requirements of these documents or specific exceptions with rational. In addition, certain Articles/Provisions are to be proposed by the offeror.

L-II-4
PERIOD OF PERFORMANCE

The contract period of performance is contemplated to begin approximately July 1988 and continue 60 months beyond the availability of a launch ready CDSF. The offeror shall specify the availability date (no later than September 30, 1993) for the offeror's CDSF and the completion date for inclusion in ARTICLE F-3--Period of Performance.

L-II-5
CONTRACT ADMINISTRATION SERVICES REPRESENTATIVES

In order to facilitate evaluation, the offeror agrees to make available to representatives of Defense Contract Administration Services Region (DCASR), or Defense Contract Audit Agency (DCAA), upon request by such representative, a copy of the proposal furnished to the Government.

L-II-6
EXCERPTION OF PROPOSAL PROVISIONS

The Government reserves the right to incorporate by reference or excerpt portions of the successful proposal for use as final contract language.

L-II-7
PREQUALIFICATION CRITERIA

Since the purpose of this procurement is to foster United States industrial development and commercialization in space, participation in this procurement by prime contractors and major subcontractors is restricted to United States industry. Major subcontractor means an entity who performs any effort of $500,000 or more. (See K-20 Domestic Source Certification)

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March 24, 1988
9:00 AM

SUBSECTION L-III

SPECIFIC INSTRUCTIONS FOR PROPOSAL PREPARATION

It is NASA's intent, by providing the instructions set forth below, to: solicit information that will demonstrate the offeror's competence to successfully meet the requirements in the Statement of Work, permit NASA to determine the offeror's capability to successfully accomplish the effort required to place the CDSF in service, and permit a competitive evaluation of the offeror's proposal. Since this is a Commercially Developed Space Facility, the offeror's response to the RFP shall provide adequate detail to enable the Government to evaluate the offeror's capability to provide a CDSF which meets the requirements of the Statement of Work. These instructions are considered a minimum list of items that should be addressed in the offeror's response.

Of critical importance in this solicitation is the offeror's providing convincing evidence that it can obtain the private financing necessary to support the full development and sustain the operations of the CDSF. Details are discussed below under Section 1 - Financial Capability.

The offeror shall submit a firm fixed price proposal for the Government's lease of 70% of the usable volume and related capabilities of a CDSF which meets the minimum capabilities as outlined in the Statement of Work for a period of five years. The offeror shall also provide approaches to accommodate fixed annual Government funding scenarios of $80 million and $140 million (in 1988 dollars) for a period of five years. Additionally, optional prices shall be provided for periods up to five years beyond the initial 60 months.

In addition, offerors may submit innovative approaches, with accompanying descriptive data, which meet the minimum technical capabilities outlined in the Statement of Work. Innovative approaches, if any, shall be described in a separate volume with a page limitation of 25 pages.

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L-III-1 VOLUME I: BUSINESS PROPOSAL

1. The Business proposal (Volume I) shall be structured as follows:

Section 1 - Financial Capability

Section 2 - Business Approach

Section 3 - Approach to Commercialization

Section 4 - Cost

Section 5 - Experience and Past Performance

Section 6 - Other Factors

Section 7 - Approaches for Government Funding Scenarios

2. Section 1 - Financial Capability

The offeror must demonstrate its capability to perform the Statement of Work without resort to government financing, (other than lease payments) during the CDSF development and operations phases. Failure to provide substantiation with properly signed commitments from qualified sources and/or corporate guarantees sufficient to cover all of the offeror's development cost may result in nonselection of the offeror's proposal.

The offeror shall submit a copy of the most current and prior two years Certified Stockholders Report (not included in page limitations) and all other financial data required to substantiate its financial capabilities for performing the Statement of Work as well as its experience in developing and financing large capital investment projects. In addition, the offeror will supply substantiation data for all venture capital including all lines of credit. This substantiation shall include, as a minimum, signed agreements (not included in page limitation) from banks and other creditors stating the amounts of credit available and the repayment schedule. The source of

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security required for these loans shall be stated. Also, state the percent of the total funds required that will be provided by borrowed capital. Provide a proforma cash flow analysis for 10 years, reflecting revenues and costs, for the CDSF lease period, including the development and operations phases, and the internal rate of return on equity and on total investment.

For business arrangements (teaming, or significant subcontractors, over $25 million) define and submit a copy of each agreement (not included in page limitation) and describe each entity's corporate capability for providing what is required in the time requested under each agreement. The same level of financial capability information shall be submitted for each major subcontractor (over $25 million).

The offeror shall (1) describe its contingency recognizing that termination liability may not be funded, and (2) demonstrate its understanding of the impacts of the lack of Government indemnification.

3. Section 2 - <u>Business Approach</u>

The offeror's proposed business arrangement regarding the lease of volume and associated services on the CDSF shall be described in detail. The offeror shall describe (1) arrangements relating to payments, (2) deductions (service outage credit) resulting from reductions in or lack of availability of leased volume and associated services due to the facility's service outage, and (3) lease terms/payments when an acceptable CDSF has been made available but has not been launched. Offeror shall describe its proposed arrangement for buying back unused government lease capacity, if any, and provisions regarding government subleasing of its unused capacity, if any. Also, address any special commitments regarding reliability, warranty, most favored customers, etc. In this section the offeror must provide a vulnerability assessment, showing its exposure, as part of the business plan. This assessment should highlight the offeror's understanding of its risk, including the impact and uncertainty of federal government lease commitments.

The offeror shall demonstrate its capability to provide for the availability of a CDSF on or before September 30, 1993. Major milestones and dates for meeting the required completion date shall be included. Timely on-orbit capability is central to the Government interest. CDSF capability available earlier than September 30, 1993 will receive special consideration. If early delivery is proposed, the offeror shall provide complete rationale to support the delivery date, including manifesting plans, anticipated date for beginning the lease, and proposed payment plans.

If deferred payment is proposed for Launch Services, the offeror shall provide a deferred payment plan and/or arrangement. The current base price for a Shuttle launch is $ (TBD*) in 1988 dollars.

The offeror shall propose an approach for user integration, launch support, and launch and orbit operations services (including up and down data links). The offeror shall describe its plans to use NASA for any of these services, including what will be required to obtain these services and commitments from the government.

Revenue generating strategies should be clearly presented. This should include, as a minimum, a process for valuing such onboard resources as power, venting, communications, and use of crew time.

4. Section 3 - <u>Approach to Commercialization</u>

The offeror shall describe its approach to marketing volume and associated services to industry. The offeror shall demonstrate an understanding of the user community needs including anticipated private sector, Government, and Government-sponsored research and development and describe its approach to meeting these needs. The offeror shall describe its plan to develop a customer base other than the U. S. Government, including projections and timing for phasing from U. S. Government to commercial customers. The offeror shall describe any pricing and payment provisions. An evaluation will be

* The costs and contractual arrangements for launch and resupply using the STS have not yet been determined.

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made of any customer commitments already established and the degree of commitment through signed agreements, letters of commitment, letters of interest or any other evidence of interest. If commercial customer commitments exceed initial allotments of leased volume, they will be viewed as enhancing the viability of the offeror to become independent of the government. The offeror shall describe its approach to manifesting and prioritizing of customer payloads. If the offeror has developed a proposed standard commercial customer lease, a copy should be provided (This is excluded from the page limitation).

5. Section 4 - Cost

The offeror shall provide the monthly lease price for the Government's lease of 70% of the usable volume and related capabilities of a CDSF which meets the minimum capabilities as reflected in the Statement of Work for a period of five years.

Certified Cost and Pricing Data are not required to support the offeror's lease price(s). However, in order for the Government to assess the proposed lease price(s), evaluate the offeror's understanding of the requirements, and establish the best buy for the Government, the following information shall be provided:

a. A brief description of the CDSF and major subsystems required to provide the leased services proposed for with a cross-reference to the technical proposal for a detailed description.

b. Estimated cost of the CDSF and each major subsystem (time-phased by year).

c. Definition of and cost schedule for the CDSF defined standard user interface and resource allocation (power, energy, heat rejection volume/weight, venting, communications, data handling), per unit of user accommodation defined by the offeror which is included within the lease price as a standard CDSF service.

d. Definition of and cost schedule for the CDSF defined optional or non-standard-to-the-lease CDSF service for interface and/or resource adjustments (power, energy, heat rejection, volume/weight, venting, communication, etc.) available to the Government as an additive cost to the lease price.

e. Definition of and cost schedule for CDSF defined standard and optional services for analytical/physical integration, launch and recovery for government experiments subsequent to the initial payload complement. Such services are not included in the base lease price.

f. Description and estimated cost for STS standard and optional services (time-phased by year)

g. If an Expendable Launch Vehicle (ELV) is used for launch, a description and estimated cost of the ELV and associated services.

h. Operations estimated cost (time-phased by year)

i. A discussion of the offeror's approach for amortization of CDSF costs

j. Break-even expectations

k. Risk

l. Offeror's assumptions as to commercial payload contributions.

m. Annual minimum acceptable termination liability and rationale.

In addition, the offeror shall provide a monthly price for up to 5 years of CDSF services beyond the initial 60 months for the volumes and associated capabilities noted below:

	Monthly Rate per Percentage of Capabilities				
Volume & Associated Capabilities	1st Year	2nd Year	3rd Year	4th Year	5th Year
1%-10%					
11%-25%					
26%-50%					
51%-70%					
71%-100%					

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6. Section 5 - Experience and Past Performance

a. The offeror shall provide a listing of all related technical experience and contracts it and proposed key subcontractors have performed during the past three years. The listing shall identify the contract, project and names, addresses, and telephone number of responsible technical personnel and Contracting Officers who have knowledge of the offeror's and subcontractors' performance. Contracts which were terminated should be included in this listing. Past performance and experience data should cover the offeror's qualifications in all areas of this RFP Statement of Work.

b. Company Experience

The offeror shall describe the company's experience and how this experience will benefit the Government if the proposer were awarded this contract. Experience should also be included for any proposed teaming, joint venture, or significant subcontracting arrangement. Of special significance is any experience the offeror's company has that relates closely to this planned procurement to include the following areas or related areas:

(1) Large commercial endeavors,

(2) Systems integration, interface and coordination of spacecraft and launch vehicles,

(3) Production of space hardware; development and maintenance of space systems software,

(4) Fixed price type contracting mode,

(5) Subcontractor management

(6) History of cost control and accuracy of estimates, and

(7) Materials processing in space

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c. Past Performance

In addition to the narrative referred to under paragraph a, offerors shall complete the enclosed questionnaire (Form EXP 1) on Company Experience and Past Performance. A separate form shall be submitted for each of the offeror's three most pertinent and most recent Government contracts. In the event that a teaming, joint venture, or significant subcontracting arrangement is proposed, references must be submitted for each participating firm.

7. Section 6 - Other Factors

a. Make-or-Buy Program

The proposal shall contain a make-or-buy plan, which reflects the make-or-buy decisions on major systems and subsystems and all other subcontracts over $500,000 and reasons for the selection of the subcontractors.

b. Utilization of Small Business Concerns and Small Disadvantaged Business Concerns

The offeror shall indicate in the proposal the total amount of subcontracting and the dollar value and percentage of subcontracting to Small Business and Small Disadvantaged Business concerns.

c. Equal Opportunity Compliance

Explain the offeror's policy (including those policies of planned subcontractors with contracts of $1,000,000 or more) on providing equal opportunity in recruiting, hiring, placing, training and promoting minorities and women. If there is an anticipated deviation from present policy, please explain.

Discuss the role and responsibilities of the individual responsible for administering the Equal Opportunity Program.

Describe procedures for resolution of complaints or allegations of discrimination within the company.

State the date of the most recent EEO Compliance Review conducted by an agency of the U. S. Government of the proposer and any subcontractors with contracts of $1,000,000 or more. Identify the agency which conducted the compliance review and discuss the results of the review.

d. Labor Management Relations

Offerors (including significant contractors over $25M) should indicate the methods to be utilized to promote and maintain harmonious labor relations and provide a proposed labor relations plan for all work required under this procurement which will be performed on a Government site.

Identify the individual responsible for labor relations at the local level. Identify the responsible official's position in the proposed management organization chart.

Explain the degree of autonomy of the local labor relations personnel. Briefly describe Division and/or Corporate role (if any) in providing labor relations support to this contract. The following information should be included:

a. Total company work force.

b. Number of employees unionized.

c. Total number of labor agreements.

d. Total number of unions which represent company employees.

e. List the principal unions your company deals with.

f. Number of strikes (last 10 years).

g. Company experience in handling arbitration cases.

h. Company experience in court cases arising out of labor problems.

i. Company experience in NLRB cases.

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2. <u>Section 1 - Launch System Interfaces and Operations</u>

a. Initial Launch Services: For the launch service of choice, the offeror shall describe in detail the CDSF utilization of: (1) standard interfaces, (2) services, (3) capabilities, (4) revisit interval, and (5) operations from launch site integration to deploy operations. Any deviations from the standard launch service operations for the system of choice shall be described in detail, including the rationale for the deviation. The offeror shall include any operations or interfaces which exceed the current capabilities. Any deviation that requires changes to launch system design, operations, or facilities are discouraged.

b. STS Interfaces for Mission Servicing: The offeror shall describe in detail the CDSF utilization of any standard STS interfaces, services, capabilities and operations. Any deviations from these standard interfaces shall be defined as optional services and noted by inclusion in a list of CDSF-required STS interfaces and operations and shall be described in detail. Any changes to STS systems design are discouraged.

c. CDSF Verification/Certification/Safety: The offeror shall provide a comprehensive description of the proposed planning to satisfy the safety requirements of NHB 1700.7B and KHB 1700.7 including verification and certification of the CDSF. This shall include any materials control plans, and product assurance plans which support the certification process, as well as planned organization structure, facilities, and GSE to be used.

d. ~~Utilization of Government Faciliti~~es: The offeror shall thoroughly describe the utilization of Government facilities for training, test and checkout prior to KSC processing; use of the TDRSS for command and telemetry acquisition; use of any TDRSS ground processing facilities, and any necessary post-flight sample removal/processing at a landing site. The offeror shall define the planned organization and staffing in the Mission Control Center at JSC and the appropriate interfaces to t~~he control services/~~facility provided by the CDSF developer.

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Present a description of the Solar Array Subsystem (or other power source), its performance characteristics and control system. In consideration of the importance of maintaining a microgravity environment, offerors shall provide a definition of acceleration disturbances anticipated to be introduced to the facility as a result of any solar array maneuvering both in the attached-to-Orbiter and free-flyer modes. The data must address acceleration vs frequency, duration of acceleration and planned frequency of operation. Other potential sources of disturbances to the microgravity environment shall be identified, such as attitude control, and quantified. The data shall be presented in either a power spectral density or shock response spectra format.

Discuss the numbers and types of any batteries used in the CDSF electrical power system. Define the useful lifetime available. Define and discuss the ground processing requirements and in-flight services or changeout required for the batteries. Define the safeguards provided.

The offeror shall discuss in a summary fashion the approach to provide the flight software to cover attitude control, sequencing, telemetry, command and redundancy management.

b. CDSF Flight Operations: Define the generic performance capabilities of the CDSF including any system limits in the different operational modes. Define key events for a typical mission including flights for servicing of the facility and experiments. The offeror shall discuss the CDSF flight operations activities and the proposed approach to providing support to the following: checkout and verification of flight operations services/facilities; conduct of in-flight operations while the CDSF is crew-operated attached-to-Orbiter; and flight operations in the free-flyer mode. Discuss any potential in-flight contingencies that can occur while the CDSF is in the Orbiter payload bay and the corrective actions that can be taken. Discuss any potential EVA requirements for contingency operations. Discuss the operations required while the CDSF payload element is in the Orbiter payload bay to check out the CDSF element and to initialize the facility for free flight.

Define the planned organization and staffing in the control services/facilities to support these activities. Define the contractor facilities and capabilities planned to be used for the real-time support. Also define the NASA or other facilities required to support the CDSF operations. Identify the top-level communications and data requirements to interface with NASA or other proposed facilities. The offeror's approach to providing training in the CDSF operations for NASA operations personnel shall be defined.

Identify the developer provided operations software.

4. Section 3 - User Accommodations

The offeror shall describe in detail its approach to providing for user accommodations as outlined in paragraphs 4a-f below. A user accommodation handbook format would satisfy this requirement.

a. The offeror will define the planned organization and staffing, contractor facilities and capabilities, and approach to providing the following:

- Government and commercial experiment integration and checkout
- Integrated payload checkout and acceptance verification
- Support to experiment late stowage requirements
- In-flight experiment operations while the CDSF is in the attached-to-Orbiter crew-operated mode
- In-flight experiment operations while the CDSF is in automated free-flyer mode
- In-flight experiment servicing/changeout and sample recovery/stowage

The offeror shall propose the approach for providing on-orbit communications with the CDSF in both the crew-operated, attached-to-Orbiter mode and free-flyer mode. The proposal will include all CDSF on-orbit TDRSS service requirements in sufficient detail for NASA to conduct an overall TDRSS mission loading analysis. CDSF requirements for additional reimbursable Office of Space Operations services/resources will be defined in sufficient detail for NASA to perform a full assessment of the impact on other NASA programs. The offeror shall describe the flow of both data and commands from the CDSF through the TDRSS, including any Government or other throughput facility to the CDSF control services/facility.

e. Launch/Landing Site Operations: The offeror shall thoroughly describe the approach for processing the CDSF elements at the launch and landing sites. The offeror shall describe the mechanical, electrical, servicing and any other GSE required to support the CDSF and associated elements during ground processing at KSC. Describe each piece of GSE, its function and where it will be required. Define the KSC facility resources required to support the GSE. Also, the offeror shall include the KSC, Cape Canaveral Air Force Station (CCAFS), contractor facilities and support services to be used, as well as their availability. The offeror shall discuss KSC and CCAFS support service requirements and agreements as appropriate to secure these services, and shall define the interfaces required between the CDSF elements with the Orbiter and the ground facilities for the pre-launch and launch countdown operations. The offeror shall describe how the interfaces between the CDSF elements and the launch facilities have been or will be verified prior to arrival of the flight ready CDSF. Discuss the tests needed to check out the CDSF elements and their interfaces, identifying any new or revised requirements for KSC support. Discuss the methods of accomplishing hazardous operations such as flight pressure checks, servicing and ordnance installation. Include a schedule for the launch site processing of each CDSF element referenced to arrival at the launch site. Discuss the real time contractor support proposed for launch site test and launch operations.

Discuss the requirements for landing site operations including the case of an Orbiter landing prior to CDSF deployment on-orbit. Identify any safing or hazardous operations and the timelines for accomplishing them. Define a plan for providing any required GSE to the primary or contingency landing site.

f. Understanding the NSTS and/or ELV Integration Process: The offeror shall demonstrate an understanding of the NSTS and/or ELV integration process. This shall include a discussion of integration responsibilities, generation of required documentation, participation in joint reviews and implementation of integration activities. The offeror shall further support this discussion with an appropriate schedule showing the CDSF-unique integration activities which will correlate to the integration schedules.

g. CDSF/Experiment Integration: The offeror shall describe the approach to integration at both the experiment and facility levels including physical and analytical integration activities. All activities associated with integrating the experiments, both government and commercial, into the CDSF and the methods for verifying the interfaces of the CDSF with the STS will be identified. This discussion shall include schedules showing experiment integration into the CDSF, as well as examination of each experiment and the CDSF to assure that the phased safety review requirements are satisfied. Supporting documentation schedules shall be included.

h. Coupled CDSF/STS Flight Analyses: The offeror shall describe any CDSF STS analyses required to assess and prepare for the attached operations of the CDSF and STS. Identify the types of analysis, e.g., flight control system interactions, etc., and the specific methods of analysis required.

3. <u>Section 2 - CDSF Design and Flight Operations</u>

a. System Description and Capabilities: The technical proposal shall include a comprehensive technical description of the CDSF design covering the configuration of each major hardware element and its systems. Include diagrams to show major features of the design. In addition, analysis and/or rationale must be provided to support the capability of the planned design to meet the identified user requirements, to include at a minimum, vacuum venting to space, power generation, heat rejection, and a microgravity environment, in the free flyer mode, of 1×10^{-6} g (for frequencies below 0.1 Hz) at the center of gravity (CG). (The CG shall be located within the pressurized volume of the CDSF and available to users.)

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Describe the accommodations of each CDSF element, including dimensions of the flight system installation in the Orbiter Payload Bay. Describe the primary structural design including the materials used.

Illustrate how components of the various subsystems are accommodated in the CDSF structure and their accessibility for maintenance or replacement during flight and ground operations. Describe the various mechanical systems used in the CDSF. Describe any ordnance subsystem and any interfaces with the STS.

The offeror shall present data showing the Orbiter payload weight and center of gravity for each CDSF element and any mission unique items.

The offeror shall discuss the approach to thermal control of the various CDSF systems and define the experiment standard interfaces for cooling/heat rejection. Include diagrams of any heat transport fluid systems and discuss the components. State the appropriate primary performance characteristics in both the crew-operated attached-to-orbiter and free-flyer modes.

The offeror shall present a description and diagrams of any CDSF propulsion system and altitude control systems and their components. State the appropriate primary performance characteristics. Discuss the thruster design including the thrust level. The offeror shall present a preliminary analysis of the propellant requirements for a typical mission including allowances for dispersions and margins available. Propellant loading capabilities shall be presented. Describe the pressurization systems and present appropriate factors of safety data for any systems with pressure requirements for ground operations and flight.

Discuss the proposed CDSF overboard experiment vent system and state the system performance characteristics, i.e., mass flow rates, vacuum level capabilities and timelines. Define locations, standard interfaces and discuss system operation, safety and control.

The offeror shall discuss the proposed approach to preserving a habitable "shirtsleeve" environment while in the CDSF in the attached-to-Orbiter crew-operated mode. Discuss the approach to providing and maintaining a nominal sea level pressure in the CDSF while in the free-flyer mode. Describe any proposed atmospheric makeup system. Discuss the approach to pre-conditioning the CDSF atmosphere prior to attached-to-Orbiter crew operations during revisit missions. Discuss instrumentation, atmospheric sampling techniques and timelines required.

The offeror shall present a description, including diagrams, of each subsystem of the avionics system. The description shall include the computer, power distribution system, instrumentation system, telemetry system and the command and data uplink system. The description will include the system operational capabilities in both the crew-operated attached-to-Orbiter and free-flyer modes. In discussing the on-board computer system include an analysis of the on-board memory requirements, capabilities and margins available. Describe the protection provided to prevent or minimize the effect of electrical power interruptions or single event electronic upsets on the on-board avionics. Identify the electrical power requirements (time history profile) for the mission and the margins available in the crew-operated attached-to-Orbiter mode. Discuss the CDSF instrumentation systems including types of measurements planned to support the experiment complement. Discuss the plan to accommodate the experiment requirements for launch site checkout, if required, and in-flight operations. Define the proposed mode for verifying the RF link from the CDSF to TDRSS while the CDSF is in the Orbiter payload bay. Define the command capability and requirements for nominal and contingency operations in both the crew-operated and free-flyer modes.

To demonstrate compatibility with an extended duration orbiter, the developer shall describe:

(1) Additional stowage provisions in the CDSF for crew expendables.

(2) The CDSF capability to supply necessary power for all CDSF subsystems operations and experiment operations while attached (docked) with the Orbiter for up to 25 days.

(3) Solar array operations to track the sun to support power generation for the facility while attached (docked) with the Orbiter and in the free-flyer mode.

- o Post-landing sample recovery/experiment deintegration, to include support of contingency landing both prior to CDSF deployment on-orbit and for nominal end of mission return to Earth for servicing flights.

b. Describe the CDSF-provided services/facilities for Government and commercial experiment developers for performance of experiment integration and test support activities. Description should include any areas set aside for (1) experiment receiving and inspection, (2) laboratory space for users to assemble, calibrate, and verify the operation of the experiment and GSE before facility integration, and (3) user rooms for communication and/or data handling services during CDSF integration.

c. A description of CDSF interaction/documentation and schedule requirements on Government and commercial experiment developers will be included in the proposal. Details of documentation required by the CDSF, such as experiment integration and operating procedures, hazards, constraints and safety shall be provided.

d. Define the standard CDSF-to-experiment interfaces and services, to include structural/power/thermal/Command Data Management System (CDMS), and identify, where applicable, compatibility with other known carriers (i.e., Spacelab, middeck, etc.) and adaptability to support hardware evolution to Space Station era carriers.

e. Government and commercial experiment hardware delivery schedules to support CDSF buildup and processing will be submitted for both the initial CDSF flight and, generically, for subsequent experiment changeout/CDSF servicing flights.

f. Describe the approach for establishment of an integrated timeline for on-orbit Government and commercial experiment operations/activities, including flight operations activities related to real-time adjustment to experiment timelines.

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5. Section 4 - Approaches For Government Funding Scenarios

The offeror shall describe its approach for accommodating fixed annual Government funding scenarios of $80 million and $140 million (in 1988 dollars) for a period of five years. Differences, if any, from the baseline Technical proposal shall be addressed in this section with appropriate cross-reference to the baseline proposal sections: Launch System Interfaces and Operations, CDSF Design and Flight Operations and User Accommodations.

The $80 million and $140 million annual funding scenarios must meet the minimum technical capabilities outlined in the Statement of Work.

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8. Section 7 - Approaches For Government Funding Scenarios

The offeror shall describe its approach for accommodating annual Government funding scenarios of $80 million and $140 million (in 1988 dollars) for a period of five years.

The following escalation shall be used to compute the funding available in then year dollars:

Calendar Year	89	90	91	92	93	94	95	96	97	98
Escalation (%)	4.7	5.0	4.7	5.0	5.2	5.4	5.6	5.6	5.6	5.6
Govt Fiscal Yr	89	90	91	92	93	94	95	96	97	98
Escalation (%)	4.5	4.9	4.8	4.9	5.2	5.4	5.6	5.6	5.6	5.6

Differences from the baseline business proposal shall be addressed in this section with appropriate cross-references to the baseline proposal sections: Financial Capability, Business Approach, Approach to Commercialization, and Cost. The $80 million and $140 million annual funding scenarios must meet the minimum technical capabilities outlined in the Statement of Work.

L-III-2 VOLUME II: TECHNICAL PROPOSAL

1. The proposal, as a minimum, shall describe the overall design concept of the CDSF and address the design and operations topics indicated in paragraphs below:

Section 1 - Launch System Interfaces and Operations

Section 2 - CDSF Design and Flight Operations

Section 3 - User Accommodations

Section 4 - Approaches For Government Funding Scenarios

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16. Abstract

The results of a NASA in-house study team effort to develop a concept definition for a Commercially Developed Space Facility (CDSF) are documented. The objective of this study was to perform mission definition analyses, systems and operations definition study tasks and cost estimation analyses to define a reference configuration and budget baseline for any future NASA lease or purchase procurement evaluation activity. Two configuration concepts are develped and cost estimates defined to bracket considerations for science experiment accommodation to permit future assessment of potential NASA CDSF utilization.

Volume I of this report documents science mission utilization definition scenarios, quantifies the conceptual configuration definition system performance parameters, develops benchmark operational scenarios, provides space shuttle interface descriptions and assesses development schedule activity with respect to the establishment of a proposed launch date. Estimates of the design, development, and operations cost are provided in Volume II of this report.

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